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SPAWNING MIGRATION, AGE, GROWTH, AND FOOD HABITS OF THE WHITE SUCKER, *CATOSTOMUS COMMERSONI* (LACÉPÈDE), IN THE BIGORAY RIVER, ALBERTA

by

© WILLIAM ALBERT BOND

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Spawning Migration, Age, Growth, and Food Habits of the White Sucker, Catostomus commersoni (Lacépède), in the Bigoray River, Alberta," by William Albert Bond in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The Bigoray River is a typical, slow moving, brown-water stream of west central Alberta that drains an extensive muskeg area. The fish populations of the river are small in numbers, the dominant fish being the white sucker, Catostomus commersoni (Lacépède). Adult white suckers are found in the Bigoray River only during the spring spawning migration. After spawning, the adults descend the stream and are shortly followed by most of the newly hatched suckers. Small numbers of young suckers remain in the stream each year to establish a small resident population.

White suckers of the Bigoray River were studied from October, 1968 to November, 1969. Entry of spawning suckers into the study area in May, 1969 appeared to be associated with rising water temperatures. The migration involved only mature fish ranging in age from 6 to 13 years. Spawning occurred mainly at the downstream end of a large pool. The downstream migration of newly hatched white suckers began on June 4 and took place mainly at night. Newly hatched suckers that remained in the study area attained a mean length of 42.2 mm and a mean weight of 0.89 g in their first year. The length-weight relationship for Bigoray River white suckers is described by the equation

$$\log_e W = -11.77915 + 3.10052 \log_e L$$

Back calculations of the growth histories of Bigoray River white suckers show that the fish grow at a constant rate for the first 6 or 7 years of life and more slowly thereafter.

The diet of white suckers is very diverse and consists largely of

animal material. Information is presented that shows the composition of the food to vary with the size of the fish and with the season of the year. The dominant insect species of the Bigoray River were the food most commonly eaten during the spring and summer, but fish captured in the autumn were found to have consumed large quantities of diatoms.

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Financial support was provided partly by teaching assistanceships from the University of Alberta and partly by monies from the National Research Council through operating grants to Dr. Clifford.

Finally, I am grateful to my wife Jane for her patience and encouragement throughout the study.

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INTRODUCTION

Members of the family Catostomidae are mainly confined to North America although at least two species are found in China and Siberia (Carl, Clemens and Lindsey, 1967). In North America the catostomids have a wide distribution and exploit a great variety of habitats. Within the genus Catostomus, the white sucker, C. commersoni (Lacépède), is probably the best known species. It occurs across North America from Nova Scotia to British Columbia and from Arkansas to the Northwest Territories (Nelson, 1968).

Despite its common occurrence, there have been few comprehensive studies of the general biology of the white sucker, owing, no doubt, to its low economic status. In Alberta the species has been neglected with the exception of a parasitological study by Kussat (1966).

This thesis presents data on white suckers collected from the Bigoray River, a brown water stream of west central Alberta. Although there are many streams of this type draining large areas of northern Canada, they have received scant attention from biologists. It is hoped that the present study will contribute to our knowledge of the fish fauna of such streams. The study was carried out from October, 1968 to November, 1969.

The original goal of the study was to assess the food habits of the white sucker in the Bigoray River. Considerable information has been collected on the invertebrate fauna of this stream in the past few years (Clifford, 1969), and it was felt that this knowledge could serve as the basis for a study that would compare the stomach contents of white suckers with the bottom fauna of the stream. As is

characteristic of brown water streams, however, the fish population of the Bigoray River is small. For this reason the study was expanded to include other aspects of the general biology of the white sucker. Among these were the analysis of the spring spawning migration, observations on spawning behaviour, hatching and downstream migration of fry and age and growth.

The present study is considered important for the following reasons: It represents the first comprehensive study to be done on the white sucker in Alberta. Latitudinally, it is the most northerly detailed life history study yet done on this species. Also, it appears to be the first study of its kind to treat a river-inhabiting population of white suckers, other studies having dealt with lake populations, the fish entering streams only to spawn. It is felt that a comparison of the results of the present study with other work on this species will provide a valuable insight into the biology of the white sucker.

DESCRIPTION OF THE STUDY AREA

General Area

The Bigoray River is a tributary of the Pembina River, part of the Athabasca River system and Arctic Ocean drainage (Fig. 1). Located 80 miles (128.7 km) west of Edmonton, Alberta, the Bigoray drains 200 square miles (517.8 km^2) of low-lying, poorly drained terrain. The river descends to the Pembina in a meandering way, at a rate of about 10 feet per mile (0.19 m per km).

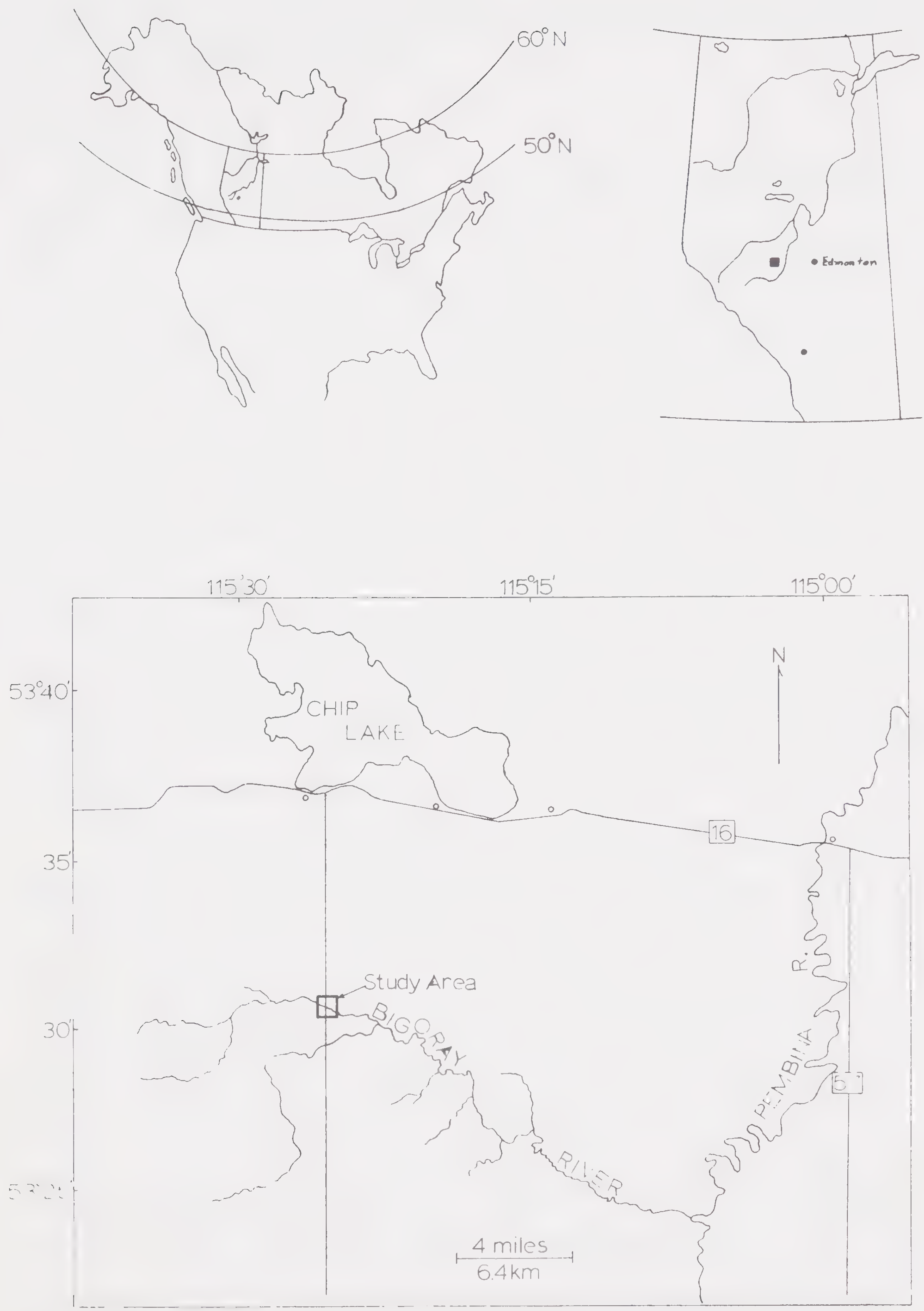
Geologically the region consists principally of sandstones and shales of late Cretaceous and early Tertiary age (Rutherford, 1928). Recent deposits are largely river terrace and flood plain deposits, in which is mixed much glacial till (Rutherford, op. cit.).

The vegetation is a mixed deciduous and evergreen woodland. Black spruce, *Picea mariana* (Mill.), and tamarack, *Larix laricina* (Du Roi), are the dominant trees in the large expanses of this poorly drained, boggy terrain. On higher ground, poplars, *Populus tremuloides* (Michx.), are common while willows, *Salix spp*. line the streams.

The soils are of the gray wooded type, this type comprising the largest soil zone of Alberta. Such soils develop under humid soil conditions, and, because of leaching, are relatively unfertile. They are usually deficient in nitrogen, phosphorus and organic matter (Ehrlick and Odynsky, 1960).

The climate is sub-arctic by the Koeppen classification, air temperatures ranging from +30C to -40C in a typical year. Precipitation averages approximately 20 inches (50.8 cm) per year, of which six inches is in the form of snow (Longley, 1967).

Figure 1. Maps showing geographical position of the study area.


60°N
50°N
Edmonton
115°30'
115°15'
115°00'
53°40'
35'
30'
N
CHIP
LAKE
16
Study Area
BIGORAY
RIVER
PEMBINA
R.
4 miles
6.4 km

The area is sparsely populated with some mixed farming peripheral to the Bigoray River water shed.

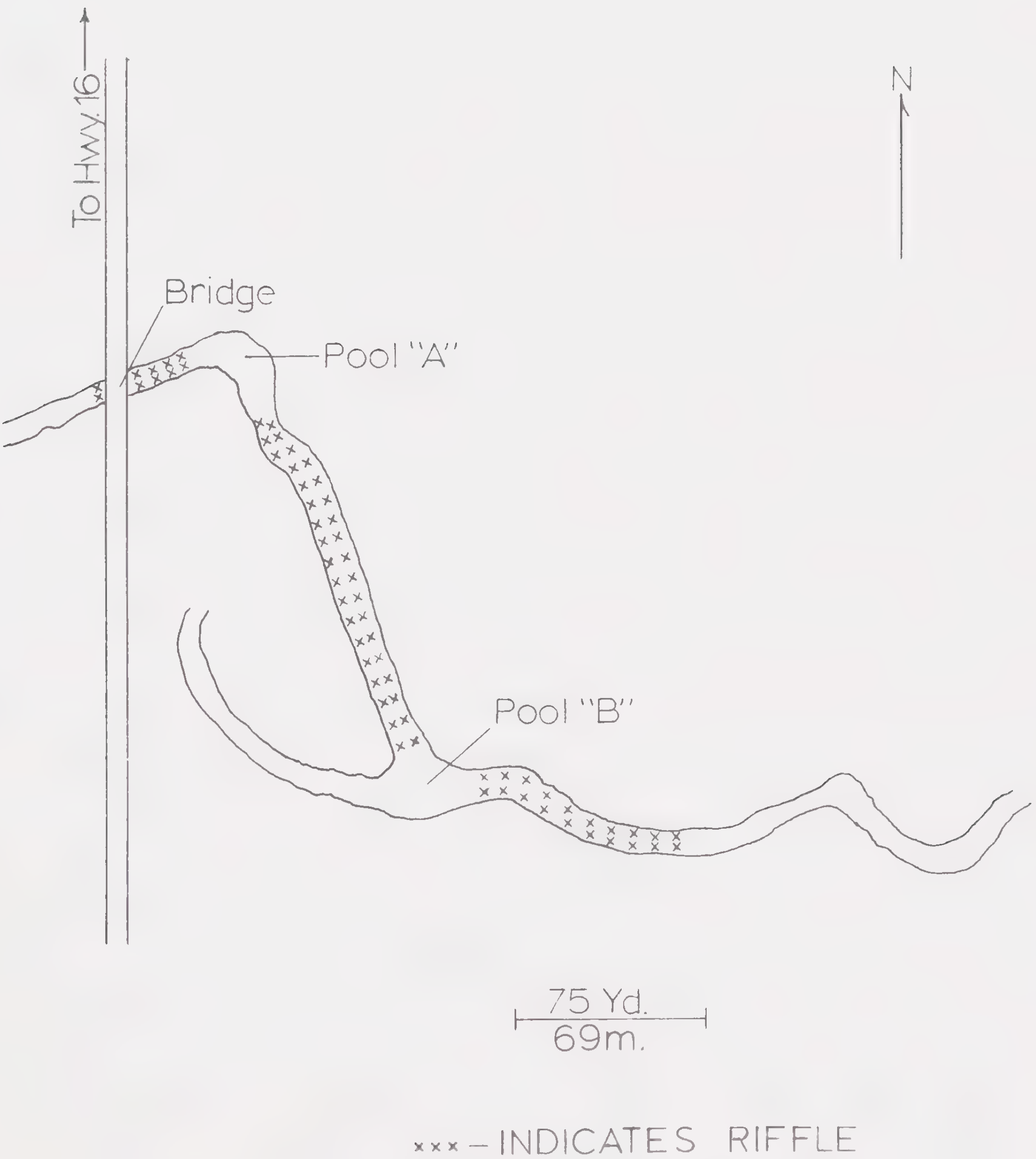
Study Area Proper

From its source at 2850 feet (855 m) above sea level, the Bigoray River flows approximately 35 miles (56.3 km) in a southeasterly direction before uniting with the Pembina River. As shown in Figure 1, the study area proper was located at approximately $53^{\circ}30'$ North Latitude and $115^{\circ}25'$ West Longitude on the North Fork of the Bigoray River. The road from Highway 16 to the town of Cynthia crosses the North Fork at one of the few riffle regions of this slowly moving stream. About $2\frac{1}{2}$ miles (4.0 km) downstream from the bridge the north and south forks of the river merge. There are no other major tributaries.

The study area included 350 yards (320 m) of the stream's channel, most of which was riffle (Fig. 2). Upstream and downstream from the study area the water is deeper and slower moving, a more typical feature of the Bigoray River as a whole.

The water of the Bigoray River is largely surface runoff. Highest water levels are recorded at the time of the spring breakup. Water level generally declines throughout the summer, but after heavy rains it may fluctuate drastically. Discharge readings are as high as 3.0 to 5.0 m^3 per second during floods and as low as 0.02 m^3 per second in late winter. The colour of the water is brown during the ice free period; the brown colour is due to the presence of organic substances, mainly humic and fluvic acids that enter the stream in colloidal form. The water becomes quite clear, however, under the ice just prior to the spring breakup. In contrast to the highly acidic water of sphagnum bogs, the pH of Bigoray water ranges from about 6.8 to about 8.2.

Figure 2. Map of the study area indicating riffle and pool regions.



To Hwy. 16
N
Bridge
Pool "A"
Pool "B"
75 Yd.
69m.
xxx – INDICATES RIFFLE

Water temperatures remain near 0C from October until April. However, even during the exceptionally cold winter of 1968-69, there was no supercooling and hence no anchor ice. Water temperatures may approach 20C during the summer, but daily fluctuations rarely exceed 3C.

In the study area the stream is as wide as 10 meters during high water, but it becomes very narrow in winter, especially in riffle regions, where there is a tendency for the water to freeze into the substrate, reducing the flow to a trickle. During the winter of 1968-69 the stream continued to flow at all times.

The stream bed in the study area is composed of mud, silt and fine gravel of a uniform size. During periods of low water, quiet backwaters appear along the edges of the riffle region, and in such areas a film of fine organic matter is deposited. Large amounts of organic debris may also accumulate at the bottom of the pools at this time. Such deposits are largely removed during high water. Both banks of the stream and the stream bed itself are unstable, and considerable erosion occurs during floods.

There are few aquatic macrophytes in the study area, but dense growths of filamentous algae, mainly Microspora loefgrenii (Nordst.), may develop during the summer. During 1968 these growths were quite dense, but they did not develop during 1969, probably because of the severe floods that occurred in this year. Except in the region of the bridge the stream is bordered on both sides by willows, Salix spp.

For most of the year the fish population of the river is small, consisting mainly of immature white suckers, C. commersoni. Other resident fish taken during the study included longnose suckers,

C. catostomus (Forster), northern pike, *Esox lucius* L., sculpins, *Cottus sp.*, and lake chub, *Couesius plumbeus* (Agassiz). Arctic grayling, *Thymallus arcticus* (Pallas), and burbot, *Lota lota* L., have also been reported from this stream (Clifford, 1969), but were not collected during the present study. Mature fish were found in the study area only during the spring spawning migration. Gill net results during May, 1969 were as follows: 88 white suckers, 17 longnose suckers, 4 pike and 1 Rocky Mountain whitefish, *Coregonus williamsoni* (Girard).

MATERIALS AND METHODS

Field work was carried out from October 1, 1968 to December 1, 1969. Throughout the winter of 1968-69 the Bigoray River was visited at roughly monthly intervals. On April 12, 1969, a field station was established at the study area. This was used as a base of operations until the end of the spawning run. From June 12 through mid-August, trips were made on a weekly basis; thereafter, trips were made every 2 or 3 weeks until the end of the study period.

Physical and Chemical

Water samples were taken from the Bigoray River once a month during the winter of 1968-69 and every 2 or 3 weeks during the ice free period of 1969. These were analyzed in the field for calcium hardness, total hardness, phenolphthalein alkalinity, total alkalinity, iron, pH, orthophosphate, turbidity and apparent colour, using a Hach model DR-EL Portable Water Engineer's Laboratory. Dissolved oxygen was determined by the azide modification of the Winkler method. Conductivity was read with a Beckman RB3 conductivity meter. A Ryan D-30 thirty day recording thermometer was suspended in the stream to monitor water temperatures throughout the study period. Water level readings were taken from a meter stick anchored in the stream. Flow and rate of discharge were determined occasionally using a Gurley No. 665 direct reading current meter. Complete chemical and physical results appear in Appendix A.

Spawning Migration and Associated Events

The Spawning population

A two-way fish trap, modified after Shetter (1938), was installed in the Bigoray River on April 15, 1969. This trap consisted of two holding boxes measuring 3' by 3' by 3', which were joined by a wire fence of ¼" mesh size. It soon became apparent, however, that such a trap was unsuitable for use in this particular stream. The heavy load of organic debris carried by the Bigoray River clogged the fence very quickly. Once this occurred, the unstable river bed soon washed out from under the fence. Gill nets, therefore, were used to capture fish during the spawning run.

A single monofilament net was operated from April 15, 1969, until the beginning of the spawning run. Once the migration had begun, this net was replaced by nylon nets of 2½", 3½" and 4" stretched mesh sizes. These remained in the stream until June 5, 1969. All nets were cleaned twice daily to remove the organic debris that had accumulated.

All fish were measured to the nearest mm (fork length) on a standard fish measuring board; they were then weighed to the nearest 0.5 ounce. These weights were later converted to grams. Scale samples were taken from the left side of each fish, above the lateral line at the anterior end of the dorsal fin. Otoliths were taken from 55 fish for the purpose of verifying the scale ages. The sex and state of gonad maturity were recorded for each specimen. Ovaries were removed from 14 mature females for use in the fecundity study. The gut tract of each fish was removed *in toto* and preserved in 10% formalin for use in the food study.

Fecundity

The ovaries of 14 mature females, captured during the 1969 spawning migration, were used in the fecundity study. All fish were nearly ripe at the time of capture, but the ova could not be expressed manually without effort. Each ovary was weighed fresh to the nearest 0.1 gram. The mean egg diameter was determined for eggs taken from the anterior and posterior portions of each ovary. This was done by aligning eggs along a millimeter ruler for a distance of at least 20 mm and dividing the distance by the number of eggs. The ovaries were then wrapped in cheesecloth, labelled, and preserved in 10% formalin.

Preserved eggs were used to estimate, volumetrically, the number of ova produced per female. A small sample of ova was taken by combining subsamples from the anterior, middle, and posterior portions of the ovary. The volume of the sample was then determined using a 5 ml microburette and a centrifuge tube graduated in 0.1 ml intervals. The sample count was then extrapolated over the volume of the entire ovary, from which the ovarian tissue had been removed. Several counts of entire ovaries were done to assess the amount of error involved in the volumetric method.

Spawning Behaviour, Hatching, and Downstream Fry Migration

The behaviour of spawning fish was observed throughout the breeding period and notes were kept describing this behaviour. Attempts to strip fish for the purpose of conducting incubation experiments failed because the females were not fully ripe when they arrived in the spawning area. The time of first hatching was determined by daily observation of developing eggs, which could be located along the edges of the stream. The time at which the downstream fry migration commenced was ascer-

tained by the use of a drift net anchored in midstream, a short distance below the spawning area. This net was checked hourly from 1800, June 5 until 0600, June 7, 1969. On each occasion the fry were removed from the net and the light intensity measured with a GE-213 light meter. The seasonal periodicity of the fry migration was not studied.

The Resident Population

The term "resident" as applied to white suckers in this thesis, refers to fish that were not members of the spawning population and were not hatched in the year of their capture; or, if hatched in the year of their capture, they had not joined in the downstream fry migration and were considered likely to remain in the Bigoray River over winter.

Resident white suckers were captured by seine, dip net, and electrofisher. Attempts to obtain fish during the winter were seriously hampered by the thick ice cover; only two specimens were collected (November 24, 1968) during the winter. An effort to remove the ice cover by the use of dynamite proved futile. Resident fish were preserved in 10% formalin in the field. Fork lengths to the nearest millimeter, weights to the nearest gram, and scale samples were taken from each preserved fish. The gut tract of each fish was removed *in toto* and retained in 10% formalin for use in the food study.

Age and Growth

The age and growth study consisted of two parts. The first was concerned with general age and growth features of white suckers, and is based on a combination of spawners and resident fish (Table 1). The second part deals specifically with first year growth and is based on 1095 fish spawned in 1969.

Determination of Age

Scale age was determined for each fish by counting annuli. Various criteria were used in determining the annuli, the most reliable of which were the crowding of circuli and cutting over in the dorsal and ventral fields. Scales of small fish (less than 90 mm) were read using a compound microscope. For larger fish, acetate impressions were made of three or four scales. These were examined at a magnification of 27X using an Eberbach #2700 microprojector. All regenerated scales were discarded. Three to five independent readings were made prior to assigning a final scale age.

To verify the scale ages, the otoliths of 55 mature fish were examined; the ages of 48 fish could be verified by this method. The otoliths were first broken through the nucleus and then examined under low power using reflected light. One drop of 100% glycerine was applied as a clearing agent.

For fish captured during the spawning migration, the edge of the scale was considered to be the last annulus. Fish captured in October and November were considered to have completed their year's growth and one annulus was added to their scale age. Thus the age of a fish captured at this time was designated as I or II rather than as 0+ or I+. Fish captured in the spring, but after June 12, were considered to have added sufficiently to their previous year's growth to warrant their exclusion from age-length and age-weight data.

Measurement of Scales

Scales of fish shorter than 90 mm were measured using a compound microscope and an ocular micrometer. These measurements were converted to conform to those made on the scales of larger fish, measured using

Table 1. Number of fish used in the age and growth study.

	Residents	Spawners	Total
Total Fish Caught	80	88	168
Length-Weight Relationship	80	86	166
Age-Length Relationship	52	86	138
Age-Weight Relationship	52	86	138
Scale-Body Length	45	83	128
Back Calculations	37	82	119

the above mentioned microprojection apparatus at a magnification of 27X.

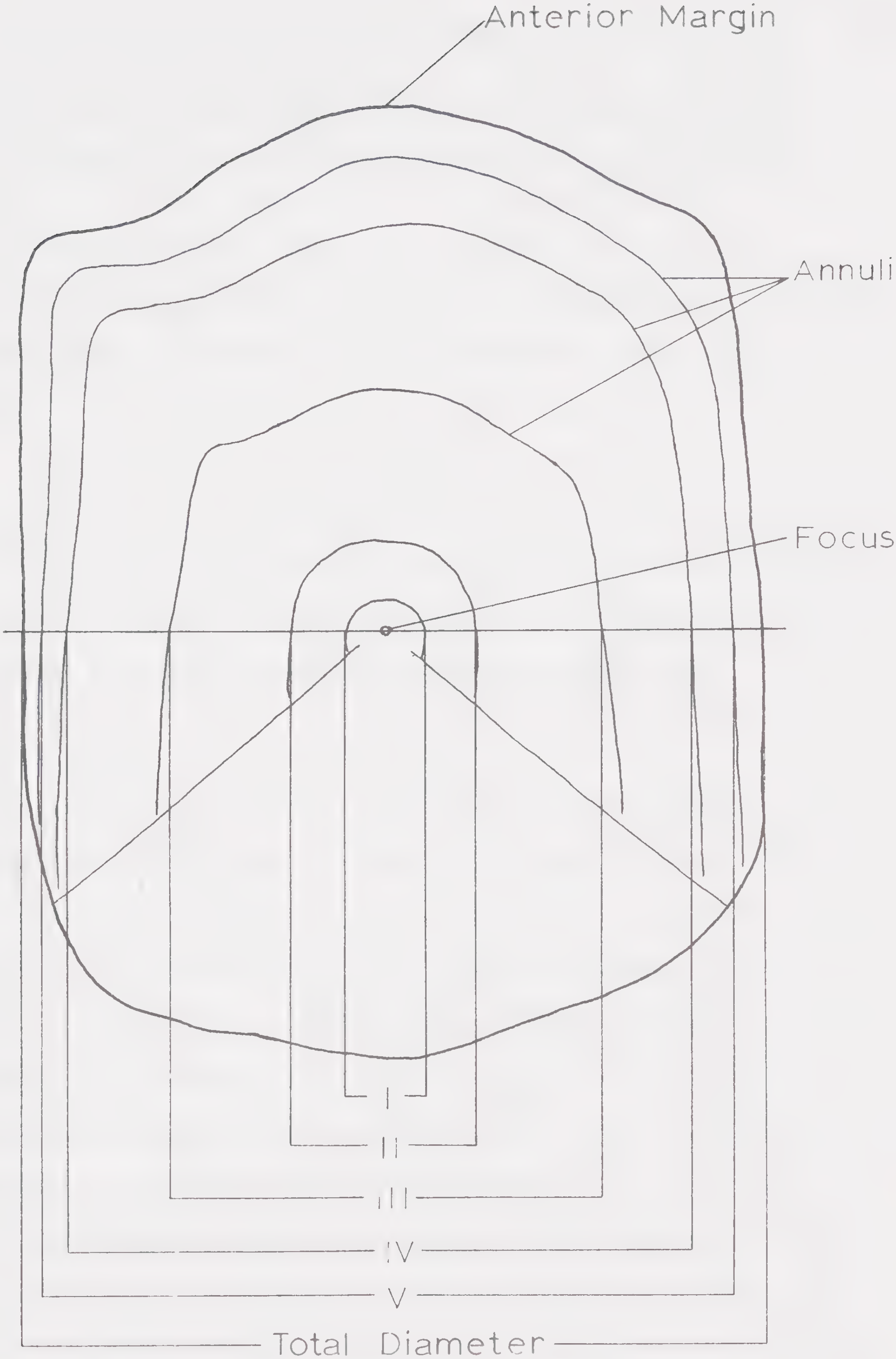
Various scale dimensions have been used in calculating growth histories of fishes, the most common being the anterior scale radius. However, Spoor (1938) determined that the best measurement for white suckers was the dorso-ventral diameter through the focus. He obtained a coefficient of correlation of 0.985 between dorso-ventral diameter and body length and a coefficient of correlation of 0.944 between anterior scale radius and body length. In my study, the coefficient of correlation was 0.990 between the dorso-ventral diameter and fork length. For this reason and because annuli are more distinct in the dorsal and ventral fields, I used the dorso-ventral diameter instead of the anterior scale radius. The full scale radius and that portion enclosed by each annulus (Fig. 3) were recorded for each scale. Measurements were made on one scale, selected at random, from each fish.

The relationship between fork length and scale diameter was expressed by the power or allometry equation

$$L = aS^n$$

where L is fork length in mm and S is scale diameter times 27 mm. The constant a is the value of L when S equals one and the constant n is the ratio of the specific growth rates of L and S. The values of a and n were derived by expanding the ungrouped data, following Lagler (1956). Fork lengths to each annulus were calculated by substituting scale measurements in the equation. This method of back calculation is known as the Monastyrsky Logarithmic Method and assumes that the logarithms of fish length and scale measurement exhibit a straight line relationship, or that

Figure 3. Diagram of a typical white sucker scale indicating the scale measurements used in the present study.



Anterior Margin
Annuli
Focus
I
II
III
IV
V
Total Diameter

$$\log L = \log a + n\log S$$

Calculated lengths were compared with those obtained for the white sucker by other workers and with the empirical data of my study.

General Growth Curves

Age-length and age-weight curves were constructed using the means of actual lengths and weights, and the determined scale ages. The equation

$$W = aL^n$$

was used to express the length-weight relationship, where W is weight in grams and L is fork length in millimeters. The constants a and n were derived by expanding the ungrouped data (Lagler, 1956).

First Year Growth

Regular samples of fish-of-the-year were collected from the time the first fish hatched (May 28, 1969) until August 1, 1969. After August 1, young fish could no longer be obtained; they apparently were washed out of the stream or displaced from the study area by floods occurring in August, 1969. Newly hatched fish were obtained by collecting eggs from the stream bed, placing the eggs in a mesh-covered quart jar and suspending the jar in the stream. The jar was checked daily and the newly hatched fish removed to 10% formalin. Fish up to 14 or 15 mm in length were collected by a dip net. Fish larger than 15 mm could avoid the dip net and a seine was used for their capture. The seine was faced with ordinary cheesecloth to prevent the loss of smaller specimens. All parts of the study area were sampled on each collecting date to assure a representative sample. Fish were preserved in 10%

formalin and all measurements were made from preserved material.

Fish were measured to the nearest 0.5 mm. Total lengths were recorded until the fish were large enough to exhibit a notch in the tail; thereafter, fork lengths were measured. Mean lengths, range in length, and standard deviation of mean length were calculated for each sample. Mean weights were obtained by weighing the entire sample and dividing by the number of fish. All means represent from 50 to 316 fish. A total of 1095 fish-of-the-year were measured and weighed.

The terminology used in this thesis to describe first year suckers is as follows: the term "fish-of-the-year" has been used in a general sense to refer to any member of the 1969 year class regardless of the state of development of the fish. The terms "fry" and "larva" have been used synonomously in referring to fish following hatching but prior to transformation to the adult form (i.e. up to a length of about 19 mm).

Food Habits

Stomach Analysis

The white sucker has no true stomach and there is no valve (Weisel, 1962). I have used the term stomach for convenience in referring to the portion of the alimentary tract that was examined for food. The gut of the young sucker is a straight tube that runs directly from the oesophagus to the vent. During development, this tube becomes coiled in a manner described by Stewart (1926). The anterior limb of the mature digestive tract proceeds as a straight tube to the region of the vent, where it doubles back to the anterior part of the coelom. The tract then makes three turns and straightens out into a posterior limb that leads to the vent. In my study only the anterior limb of the adult digestive tract

was examined. In the case where the gut had not yet become coiled, only the anterior half of the tube was examined. The methods for the capture of the fish and preservation of the digestive tracts have already been described.

For mature fish, captured during the 1969 spawning run, the stomach was cut free at the oesophagus and at the first bend of the gut. Each stomach was opened and the contents spread in a white-bottomed dish. The stomach contents were examined under low power of a dissecting microscope. All recognizable food items were identified to the most restrictive taxonomic unit possible. The food items were then counted. Mucus and the debris that was mixed with it were discarded. Each group of organisms was placed on blotting paper for 1 minute to remove the excess moisture; the organisms were then weighed to the nearest 0.0001 gram. Molluscs and cases of aquatic insects were not weighed. The results were expressed as percent frequency of occurrence, percent numbers, and percent wet weight.

Fish-of-the-year and resident fish ranged in length from 11.5 to 196.0 mm, but only 6 of the 267 fish exceeded 90.0 mm. The food items of fish-of-the-year and resident fish were not weighed and no attempt was made to estimate volume. Each stomach was opened and the contents spread in a 1 ml Sedgewick-Rafter plankton counting cell. The cell was filled with water and a cover slip applied. The entire cell was then scanned at 100X using a compound microscope. Each type of animal food organism was identified and counted. The presence or absence of algae was noted. Results were expressed as percent frequency of occurrence and percent numbers.

Bottom Fauna

Bottom samples were collected using a fine-mesh dip net (400 meshes per cm^2). Riffle samples were obtained from 10 m of the stream below pool "A" (Fig. 2). During the winter of 1968-69, pool samples were taken from pool "B". But during summer and autumn 1969, pool samples were collected upstream from the bridge. This change was necessary because pool "B" was swept clean of debris and bottom fauna during the spring flood.

Samples were returned to the laboratory and picked while the animals were still alive. Because of the large amounts of debris, the pool samples were washed through a number 20 screen (mesh opening 0.841 mm) before picking the sample. Riffle samples were not washed. The animals were preserved in 70% ethanol. All organisms were identified and each group was counted. Each group of organisms was allowed to stand on blotting paper for 1 minute to remove excess moisture and then weighed to the nearest 0.01 gram. Percent numbers and percent wet weight were determined for each taxon with the following exceptions: Chironomids (not picked from the pool samples), Molluscs (not weighed), Pelecypods and Oligochaetes (excluded from the percent numbers data).

RESULTS AND DISCUSSION

Spawning Migration and Associated Events

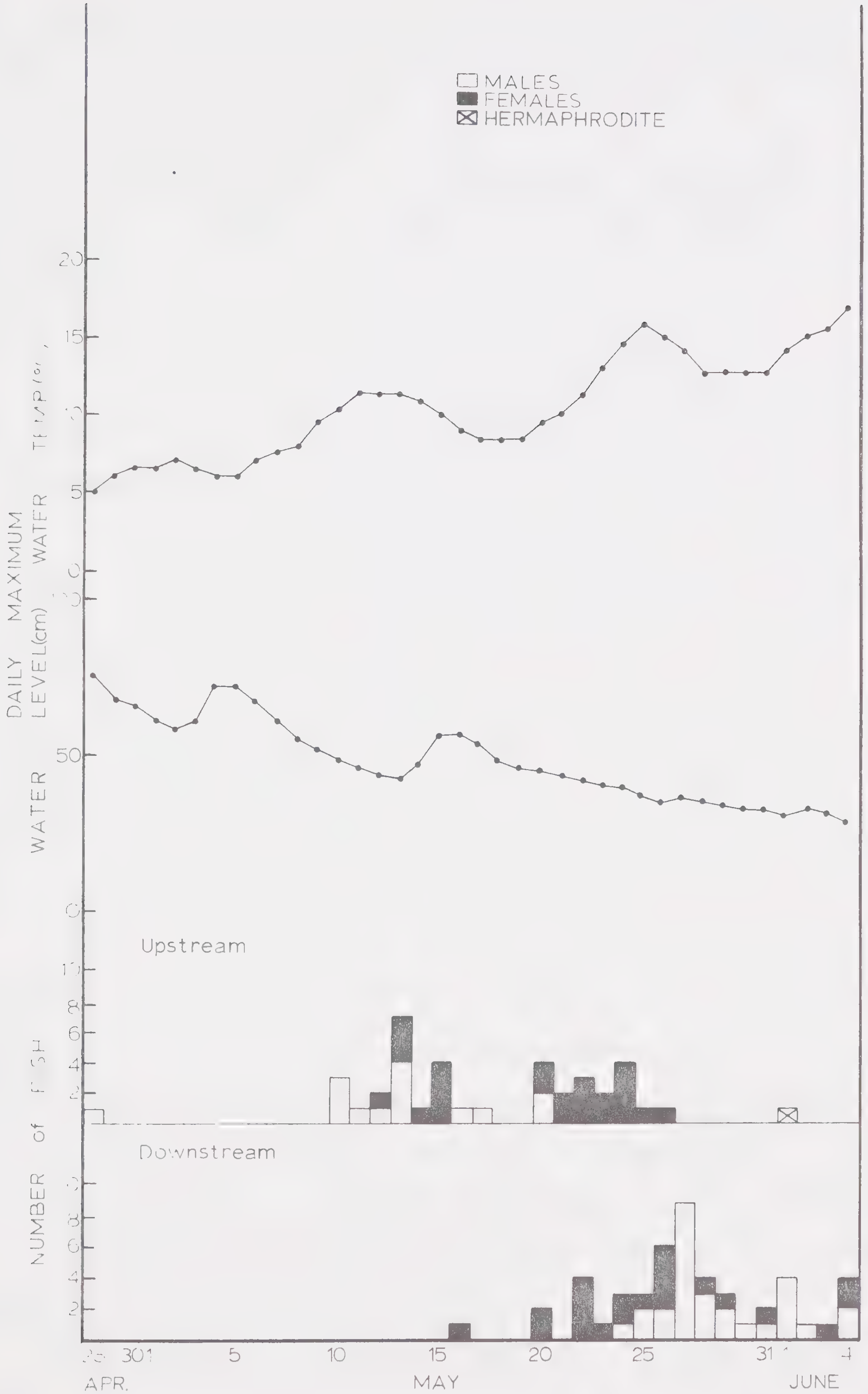
For most of the year the white sucker is generally found in lakes and larger rivers. In the spring, however, the suckers leave their normal habitat to spawn in small tributary streams. Following the breeding season the adults return to the lakes and rivers and are followed soon after by almost all the young fish that resulted from the spawning (Hubbs and Creaser, 1924).

The white sucker is most easily studied while in the tributary streams, and, for this reason, considerable information has been published on its spawning migration and breeding behaviour. Reighard (1920) published the first extensive work on the breeding behaviour of white suckers. Further work has been done by Raney and Webster (1942), Geen (1958), Tremblay (1962) and others.

Seasonal Timing of the Spawning Migration

The 1969 spawning migration into the Bigoray River study area extended from May 10 to June 4 (Fig. 4). Ripe fish moved upstream between May 10 and May 28, and the first spent fish was captured moving downstream on May 16. Actually, the first fish captured during the study was a male taken April 28 when the water temperature was only 4C. This fish was not yet fully ripe, i.e. the milt could not be expressed. The main part of the upstream migration commenced on the evening of May 10, the first day that the maximum water temperature exceeded 10C. The daily maximum water temperature dipped below 10C on May 16, and this was accompanied by a decrease in the number of upstream migrants. No fish

Figure 4. Seasonal timing of the 1969 spawning migration.



MALES
FEMALES
HERMAPHRODITE
DAILY MAXIMUM WATER TEMP(°C)
WATER LEVEL(cm)
Upstream
Downstream
NUMBER of FISH
APR.
MAY
JUNE

were captured on May 18 and 19. With the increasing water temperature of May 20 (to 9.5C), the migration resumed. Thereafter, the daily maximum water temperature remained above 10C.

Water levels generally dropped throughout the spawning period, with the exception of a slight rise between May 13 and May 16 (Fig. 4). The rise in water level at this time was associated with the same cold, rainy weather that accounted for the drop in water temperature.

Because the rise in water level and the drop in temperature occurred simultaneously, it was impossible to analyze the effect of either on the timing of the spawning run. Other workers, however, have generally concluded that the temperature of the tributary stream is the critical factor for initiating the spawning migration, and that water level is of relatively little importance. Raney and Webster (1942) reported that white suckers started to migrate when the water temperature first reached 45F (7.2C). Geen _et al_ (1966) report the critical temperature to be 10C for white suckers in British Columbia. The latter authors also found stream temperatures to be closely associated with initiation of the spawning migrations of other fish species.

My study does not deal with the initiation of a spawning migration as such. Instead it is concerned with a population that, by the time it arrives in the study area, has already travelled more than 20 miles upstream. Since a stream warms in an upstream direction from its mouth (Ruttner, 1953), it seems safe to assume that the lower reaches of the Bigoray River attained a temperature of 10C sometime before this temperature was reached in the study area. Perhaps the migrating fish proceed upstream as the water warms in an upstream direction.

If the time of the migration is influenced by temperature, one

would expect to find, at one location, temporal differences from year to year and, within the same year, temporal differences at different latitudes. Reighard (1920) states that white suckers breed in April and early May in southern Michigan. In New York State, Raney and Webster (1942) report migrations beginning on April 19 in 1939 and on April 10 in 1941. Within the same year, Geen (1958) noticed that suckers spawned earlier in the more southerly streams of British Columbia. Geen et al (1966) give May 12 and May 3 as the dates on which spawning migrations began in 1956 and 1957 respectively in a stream of British Columbia.

Although the white sucker spawns in the spring, there is, apparently, considerable variation as to the precise timing. Water temperature seems to be the most important factor controlling this timing.

Diel Timing of the Spawning Migration

A pronounced diel timing was exhibited in the migrations of both ripe and spent white suckers. Although an hourly breakdown was impractical because of the small number of fish involved, the majority of fish moving upstream were captured between 1500 hours and midnight; the most intense part of the upstream migration occurred between 2100 hours and midnight. In contrast, the downstream migration took place mainly at night, with 60% of the spent fish being caught between midnight and 0500 hours.

The daily upstream migration occurred when the stream temperatures were at or near the daily maximum. By comparison, the downstream migration usually occurred when stream temperatures were decreasing.

Sex Ratio

The sex ratio of the 1969 spawners showed no significant deviation

from unity ($^{2} = 0.10$). However, while the overall ratio was 1:1, it varied considerably throughout the duration of the run (Fig. 4 and Table II). Male suckers appear to precede the females onto the spawning grounds and to remain there longer. Males outnumbered the females in the first half of the upstream migration (until May 17) and also in the last half of the downstream migration (May 26 to June 4). Geen et al (1966) reported similar results in British Columbia.

The difference in the sex ratio in the first half of the upstream migration was probably greater than is indicated by the data in Table II. Since only a single monofilament gill net was used during the first three days of the run, the number of fish captured on these days was probably fewer than would have been taken by the more efficient nets installed on the fourth day. It seems likely that more efficient netting would have resulted in a more pronounced sexual difference during this part of the migration.

Concerning the earlier movement of males onto the spawning grounds, Mottley (1933) suggests that male rainbow trout will locate and enter the spawning streams ahead of the females because males are randomly more active than females. The difference in timing may also be associated with different rates of gonad maturation between male and female fish. In my study, all male suckers arriving in the spawning area were fully ripe. Females, on the other hand, were never fully ripe on arrival.

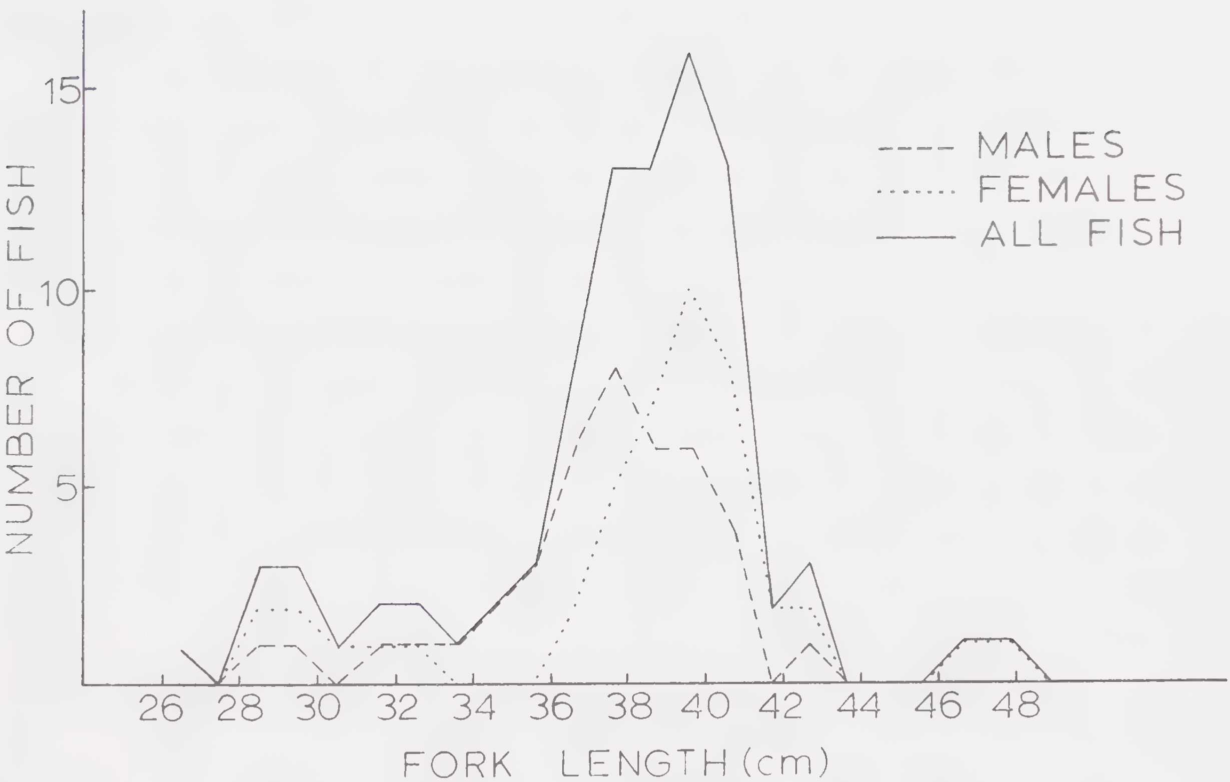
Size of Spawners

The 1969 spawning run was composed of large suckers, all of which were mature. Females exhibited a larger average size than males. The length-frequency distribution for 87 white suckers is plotted in Figure 5.

Table II. Sex ratio during various times of the 1969 spawning migration.

	Number of Males	Number of Females
Upstream Migration:		
First Half (through May 17)	12	9
Second Half (after May 17)	2	15
Downstream Migration:		
First Half (to May 26)	3	11
Second Half (May 26 - June 4)	25	10
Total	42	45

Figure 5. Length frequency distribution of white suckers during the 1969 spawning migration.



MALES
FEMALES
ALL FISH
NUMBER OF FISH
15
10
5
26
28
30
32
34
36
38
40
42
44
46
48
FORK LENGTH (cm)

The 42 males had an average fork length of 369 mm (range: 262-425 mm), while the 45 females averaged 384 mm (range: 290-472 mm).

The absence of fish shorter than 262 mm is not considered to be related to the selectivity of the gillnets. Many observations of fish on the spawning grounds failed to reveal any small suckers. It may be that the distance involved in the migration and the many obstacles along the way, rendered the journey too arduous for some suckers, selecting out the smaller and weaker fish.

Age of Spawners

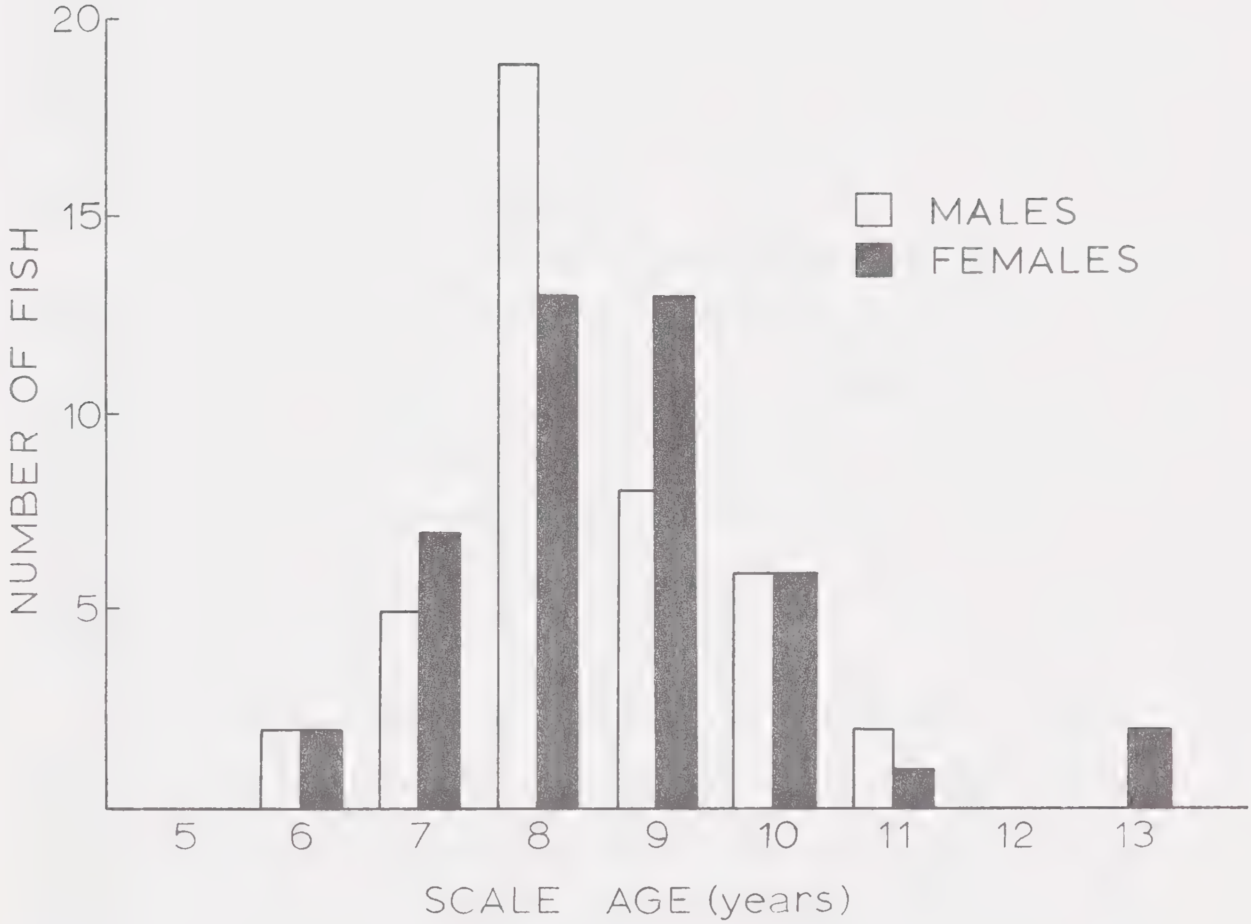
The age distribution of the 1969 spawning population is shown in Figure 6. Age determinations by both scales and otoliths revealed spawners to be from 6 to 13 years of age, with ages 8 and 9 comprising 61% of all fish.

Geen (1958) concluded that white suckers do not spawn before age six. Spoor (1938) states that males mature at 5 or 6 years and females at 6 or 7 years. I did not collect any age 5 fish. However, an age 4 male was caught in a drift net on June 6; it was found to be fully ripe and to possess small but well developed pearl organs. The fact that spawning fish had left the study area by June 4 suggests that this age 4 male, though ripe, might not have spawned during 1969. This is not to suggest that suckers in the Bigoray River do not spawn before the age of 6 years; they may spawn in some other part of the stream. However, no spent fish was captured that was less than age six.

Fecundity

The number of eggs in the ovaries of 14 mature females was estimated by the volumetric method. The reliability of the estimate was tested by

Figure 6. Age composition of white suckers during the 1969 spawning migration.


20
15
10
5
NUMBER OF FISH
MALES
FEMALES
5
6
7
8
9
10
11
12
13
SCALE AGE (years)

actual counts on five ovaries (Table III). The use of a microburette for measuring the volume of the sample produced errors of from +8.9% to -6.0%, the mean error being -0.18 percent. The negative errors might have resulted from shrinkage of some ova, which were exposed to air prior to preservation. When a graduated cylinder was used instead of the microburette, the percentage errors were +15.4% and +19.5% for two tests. These latter figures indicate that much more precise measurements are possible using the microburette instead of a simple graduated cylinder. This increased precision is especially important when dealing with large numbers of small eggs.

Complete results for the fecundity study are presented in Table IV. The estimated number of eggs per female ranged from 15,983 to 60,242 with an average of 34,502 for each female in the sample. Stewart (1926) obtained estimates of 18,000 and 31,200 eggs from two fish that were 305 and 381 mm long respectively. Raney and Webster (1942) reported the number of eggs for eight females, ranging in total length from 406 to 527 mm, to be from 21,800 to 47,800 per female.

I found an average of 628 more eggs in the right than in the left ovary. Of the 14 fish, nine contained more eggs in the right ovary. Since the ovaries of all fish had merged posteriorly, they had to be separated by hand, and the differences in egg counts between left and right ovaries may have resulted from this procedure.

The ovaries comprised, on the average, 11.8% of the total body weight of the fish. This represented the condition just prior to spawning.

Based on 24 determinations, the average egg diameter was 1.5 mm. Differences in diameter between eggs from different parts of the same

Table III. Comparison of estimated and actual number of eggs in five white sucker ovaries.

Number of Eggs per Ovary

Estimated	Actual	Difference	% Error
8861	8492	+369	+4.3
16471	15118	+1353	+8.9
18972	20153	-1181	-5.8
19465	19921	-456	-2.3
19941	21234	-1293	-6.0

Table IV. Complete fecundity results for 14 white suckers captured during the 1969 spawning migration.

Fish No.	Fork L. (mm)	Wt.(g)	Number of Eggs			Total Wt. of Ovary (g)		% Body Wt. of Ovaries	Avg. Egg Diameter (mm)		Relative Fecundity	
			Left	Right	Total	Left	Right		Left Ovary	Right Ovary	(cm)	(g)
1	282	340.2	7704	8279	15983	17.8	18.4	10.6	1.48	1.45	566.8	46.9
2	290	326.0	9689*	8492*	18181*	22.1	19.0	12.6	1.37	1.37	626.9	55.8
3	307	453.6	10098	11033	21131	23.0	26.4	10.9	-	-	688.3	46.7
4	327	496.1	12408	10981	23389	29.4	29.4	11.8	1.43	1.45	715.3	47.2
5	367	765.5	14337	14228	28565	45.4	47.8	12.2	-	-	778.3	37.3
6	371	793.8	17744	18462	36206	54.3	53.5	13.6	1.61	1.58	975.6	45.6
7	375	864.7	19680	20744	40424	54.8	57.1	12.9	1.52	1.52	1077.9	46.7
8	375	737.1	13117*	15118*	28235*	28.6	32.2	8.3	1.38	1.42	754.3	38.3
9	378	808.0	18507	21278	39785	43.2	53.0	11.9	1.47	1.47	1052.5	49.2
10	388	907.2	22016	18766	40782	49.5	59.5	12.0	1.57	1.57	1051.1	44.9
11	399	878.9	20324	21234*	41558	47.2	46.3	10.6	1.41	1.40	1041.3	47.3
12	400	864.7	20153*	19921*	40074*	49.0	48.0	11.2	1.51	1.51	1001.9	46.3
13	402	978.1	22076	26400	48476	71.5	75.9	15.1	1.59	1.55	1205.9	49.6
14	472	1545.1	29265*	30967	60242				1.76	1.76	1276.9	37.1
Avg.	367	768.5	16937	17565	34502	41.2	43.6	11.8	1.51	1.50	915.2	45.6

* Indicates Actual Count

ovary were slight, as were those between eggs from the left and right ovaries of the same fish. Egg diameters ranged from 1.37 to 1.76 mm, tending to increase with the length of the fish (Table IV). Dence (1948) found formaldehyde-preserved eggs of dwarf white suckers to average slightly less than 2 mm in diameter.

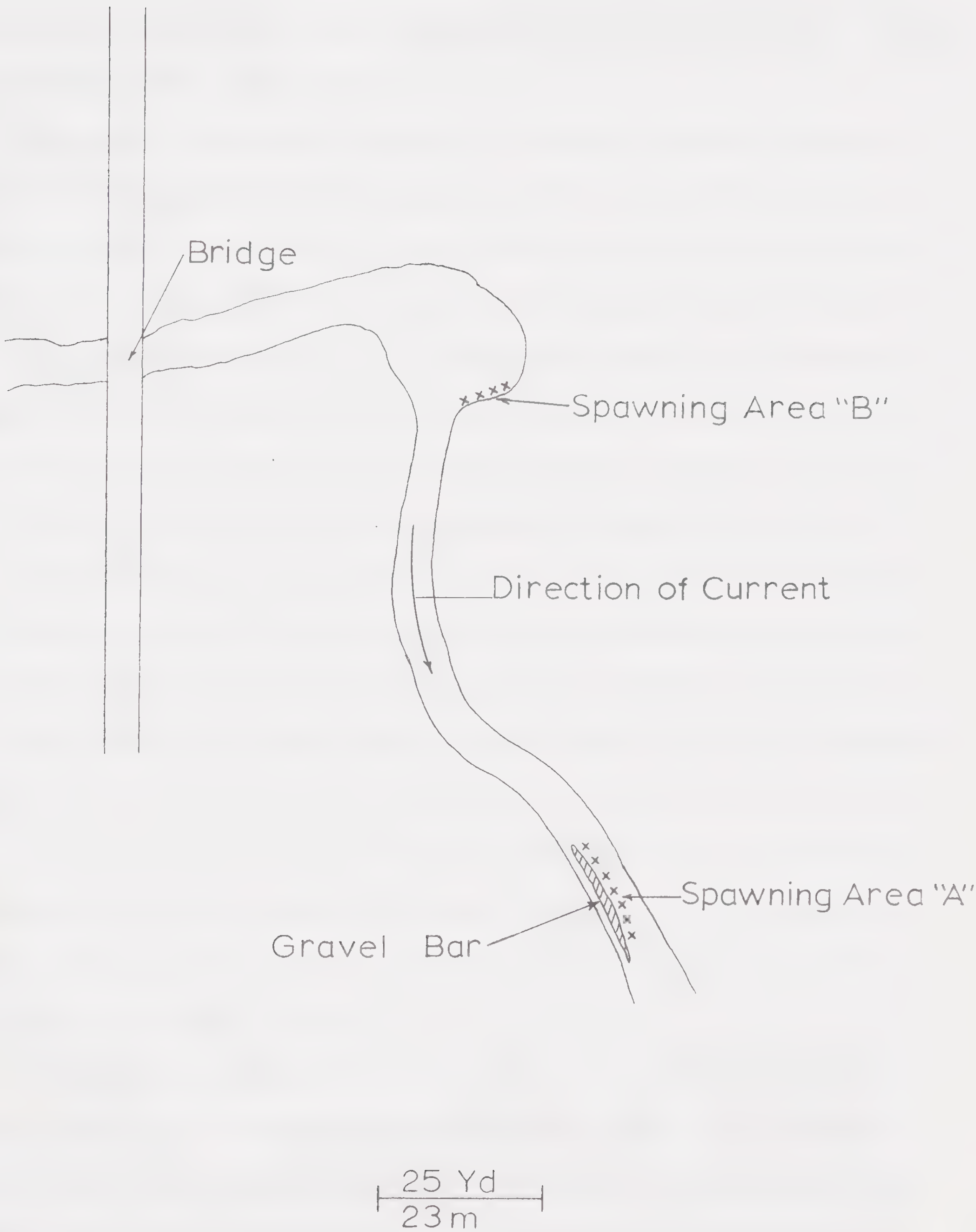
Fecundity is often expressed in relative terms. Length-relative fecundity is the number of ova per unit of body length. Weight-relative fecundity is the number of ova per unit of body weight. In my study, the average length-relative fecundity was 915.2 ova per cm of fork length and the average weight-relative fecundity was 45.6 ova per gram of body weight. These figures greatly exceed those of Raney and Webster (1942), whose corresponding values were 410.0 and 23.9 respectively.

Spawning Behaviour

As far as could be ascertained, spawning occurred in only two restricted portions of the study area as indicated in Figure 7. Spawning area "A" was located in a straight stretch of stream where the current during the spawning season was 0.75 meters per second at midstream. In this region, water, varying to a maximum depth of 30 cm, flowed over a uniform gravel bottom, the gravel particles being from 5 to 15 mm in diameter. Spawning area "B" was at the downstream end of a large pool. The current was considerably less here than in area "A" and the gravel was larger, the particles ranging from 5 to 50 mm in diameter. The pool was approximately 6 feet (1.8 m) deep in the centre and the left bank, which was undercut, afforded excellent cover for fish. Spawning was never observed at the upstream end of this pool, even though this region seemed to offer suitable conditions.

The white sucker usually spawns in the shallow, swift waters of

Figure 7. Map of study area indicating location of spawning sites.


Bridge
Spawning Area "B"
Direction of Current
Spawning Area "A"
Gravel Bar
25 Yd
23 m

small streams and over a gravel bottom (Reighard, 1920). Indeed, Geen (1958) states that white suckers have two main spawning requirements: running water less than 12 inches deep and gravel bottom. It is known, however, that white suckers can also spawn in lakes that lack both inlets and outlets (Dobie et al, 1948).

Concerning the essential features of the white suckers' spawning grounds, although area "A" more fully satisfies the requirements named by Geen (1958), Bigoray River suckers preferred area "B". Spawning was observed only once in area "A", during the evening of the first day of the migration into the study area. Thereafter, spawning was observed only in area "B". Area "B" seems somewhat similar to a spawning site described by Raney (1943); that is, white suckers spawning at the lower end but not at the upper end of a large pool in rather quiet water.

It would seem that the presence of deep water adjacent to the spawning site, and to which the fish may retreat when alarmed, is more important than a swift current. Such flight may be undertaken more easily and more rapidly if the deep water is located upstream from the spawning site.

Although spawning was observed only in the two areas mentioned, it is probable that some spawning did occur upstream from the study area. A drift net installed above the bridge on June 26 collected more than 900 fry in less than 24 hours.

The spawning behaviour of white suckers in the Bigoray River was almost identical to that described by Reighard (1920) for a population observed near Grand Rapids, Michigan. Females did not mingle with the males on the spawning grounds until ready to deposit their eggs. Instead, they remained out of sight for most of the time and were found in

the deeper water of the pool. Casual observations, therefore, would give the impression that the sex ratio greatly favoured the males. As stated earlier, this was not the case. When ready to spawn, the female drifted from deep water to the shallow water at the base of the pool, where the males waited. The spawning act usually involved one female and from three to six males. Reighard (1920) observed as many as 10 males attempting to spawn with a single female.

Male and female white suckers are easily distinguished on the spawning grounds on the basis of colour differences. However, Raney (1943) concluded that the sexes are distinguished more on the basis of behavioural than colour differences. My observations of Bigoray River suckers lead me to agree with Raney. Any Bigoray River sucker that moved rapidly across the spawning grounds was immediately pursued by a group of males, apparently attempting to mate with it. If the pursued fish was a male, or a female that was, perhaps, not ready to spawn, it would hastily retreat to deeper water.

Two unusual types of male behaviour were observed during the present study. After a successful spawning act the males lay quietly in shallow water at the lower end of the pool. With the reappearance of a female, the males immediately became active and rapidly pursued her. Sometimes the female's excursion did not culminate in a successful pairing and the female would return to deeper water. The males, now excited, did not return to their quiescent state, but instead swam actively over the spawning grounds, sometimes bumping into each other. Often the males appeared to feed, nosing into the gravel with their bodies held at an angle to the stream bed and their tails thrashing the water surface. This same behaviour by the males was witnessed after a period of time (about 15

minutes) if a female failed to appear on the spawning grounds, suggesting the possibility that this was some form of displacement activity.

Stewart (1926) reported that whenever the water temperature reached 12C, suckers were seen swimming at the surface and breaking water. He adds that they frequently "leaped out of the water for most of their length and then swam back to the bottom." The same unexplained behaviour was observed occasionally in Bigoray River suckers.

Male suckers exhibited neither territoriality nor aggressiveness toward their fellows. Such tendencies, were they to occur, would be disadvantageous to a species in which spawning requires a cooperative effort by the males.

Spawning occurred at all hours of the day and night. Dobie et al (1948) report that white suckers do most of their spawning at night. This is in contrast to the findings of Reighard (1920) who observed spawning only during the daytime. However, Reighard mentions that possibly the white sucker's breeding activities are continued at night. Geen et al (1966) suggest that longnose suckers in a stream of British Columbia cease to spawn at about 2130 hours.

Sexual Dimorphism

Male and female white suckers are easily distinguished during the breeding season by colour differences, the males exhibiting a greater intensity of the lateral reddish stripe and the white occipitolateral stripe. Reighard (1920) reports that, in Michigan, the males develop a brilliant crimson side stripe and that this brilliant colour does not appear in the females. In British Columbia, the males, instead of developing a crimson colour, simply exhibit a slight pinkish tinge (Nelson, 1968). During the first two nights of observation in 1969, male

suckers of the Bigoray River possessed the very brilliant side stripes described by Reighard. Females displayed only a small amount of pink that extended no farther than 2 inches (5.1 cm) behind the pectoral fins. After the second night, however, the intense crimson colour of the males faded, or at least was not seen; and the males then appeared as those described from British Columbia.

The cyprinids and catostomids are known to develop pearl organs, which appear prior to the breeding season and are lost after spawning. For white suckers, pearl organs are a male characteristic, although they have been reported occasionally in females (Dence, 1948). In my study these structures occurred only on male fish. One male, captured April 28, 1969, was in the process of developing pearl organs, but these were not sharp and horny like those seen later in the season. By May 27, spent males had begun to shed their pearl organs. Stewart (1926) suggests that these seasonal structures serve to roughen the sides of the male fish, making it difficult for the female to escape from the males during spawning.

The anal and pelvic fins were found to be consistently good sexual indicators. Spoor (1935), after examining a large number of morphological characteristics, concluded that these fins were the most useful features for determining the sex of adult white suckers at all times of the year. In my study, as in Spoor's, the male anal fin was relatively longer than the female. The pelvic fins of the male were angular as compared to the more rounded pelvics of the females.

Observations on Hatching and Incubation

No definitive incubation experiments were carried out in the present study. Raney and Webster (1942), however, using a constant temperature

apparatus, found the most favourable temperatures for incubation to be between 57F (14C) and 68F (20C). At these temperatures, eggs hatched in 6 to 7 days and there was little mortality. At 70F (21C) the eggs hatched in 4 days but mortality was high. Eggs were observed for 14 days at 40F (5C) but none hatched. Geen et al (1966) obtained an incubation time of 8 days at 11C.

In 1969, spawning first occurred in the Bigoray River between May 10 and May 13. Water temperatures at this time varied from 10C to 11.5C. Between May 15 and May 22, water temperature dropped, ranging from 7.5C to 10.0C, the mean being about 8.5C. For the next three weeks, May 23 to June 13, the mean water temperature was greater than 12C. One would expect, however, that the week-long cold spell between the 15th and 22nd of May would delay considerably the development of the earliest eggs.

On May 26, observations of ova in the shallow water along the shoreline of the stream revealed unhatched larvae in many different stages of development. The most advanced of these fish fit precisely the description given by Stewart (1926) for fry at the 224 hour stage (at 10C). These fry exhibited a yolk sac that was reduced to a cylindrical posterior portion and a spherical anterior part (Fig. 8a). The notochord is visible, the head is still folded on the yolk sac, and no pigmentation has yet developed. The fish at this time averaged 8.0 mm in total length.

The first evidence of hatching was seen on May 28, when several empty egg shells were found along the stream. On 30 May, 75 eggs were collected at random from the stream bed and placed in a mesh-covered quart jar, which was then suspended in the stream. The jar was checked

every 24 hours and the hatched larvae removed. The results indicate approximately 70% hatching success (Table V). This figure is a bit low because the jar was destroyed on June 4 by curious passersby.

The evidence suggests, then, that the first white sucker eggs hatched on May 28, 1969. This would be 15 to 18 days after the first day of hatching. At hatching, the fry ranged in size from 8 to 11 mm and averaged 10 mm (Fig. 8b). Reighard (1920) reported newly hatched white sucker fry to average 8 mm in total length. Stewart (1926) found newly hatched fry to average 9 to 10 mm and attributed the increased length to delayed hatching caused by low water temperatures.

Downstream Migration of Fry

After spawning, adult white suckers return downstream and are shortly followed by nearly all the newly hatched fry, the fry moving downstream very soon after the yolk sac is absorbed (Hubbs and Creaser, 1924).

In the Bigoray River, fry began their downstream migration on 4 June, 7 days after the estimated date of first hatching. Geen et al (1966) state that both longnose and white sucker fry remain in the gravel for 1 to 2 weeks prior to commencing their downstream migration.

The fry, when they began moving downstream, averaged 12.1 mm in total length and only a remnant of the yolk sac remained (Fig. 9a). The yolk sac is usually completely resorbed by the time the young fish have reached a length of 13.0 mm (Fig. 9b).

Fry migrated downstream mainly at night. As shown in Figure 10, the number of fry caught per hour increased rapidly between the onset of darkness and midnight. After midnight, the number of fry caught per hour decreased rapidly, possibly because the number of fry available for

Table V. Order of hatching for white sucker eggs collected from the Bigoray River, 1969.

Date of Hatching		No. of Larvae
May 31		1
June 1		17
June 2		20
June 3		8
June 4		6
	Total	52

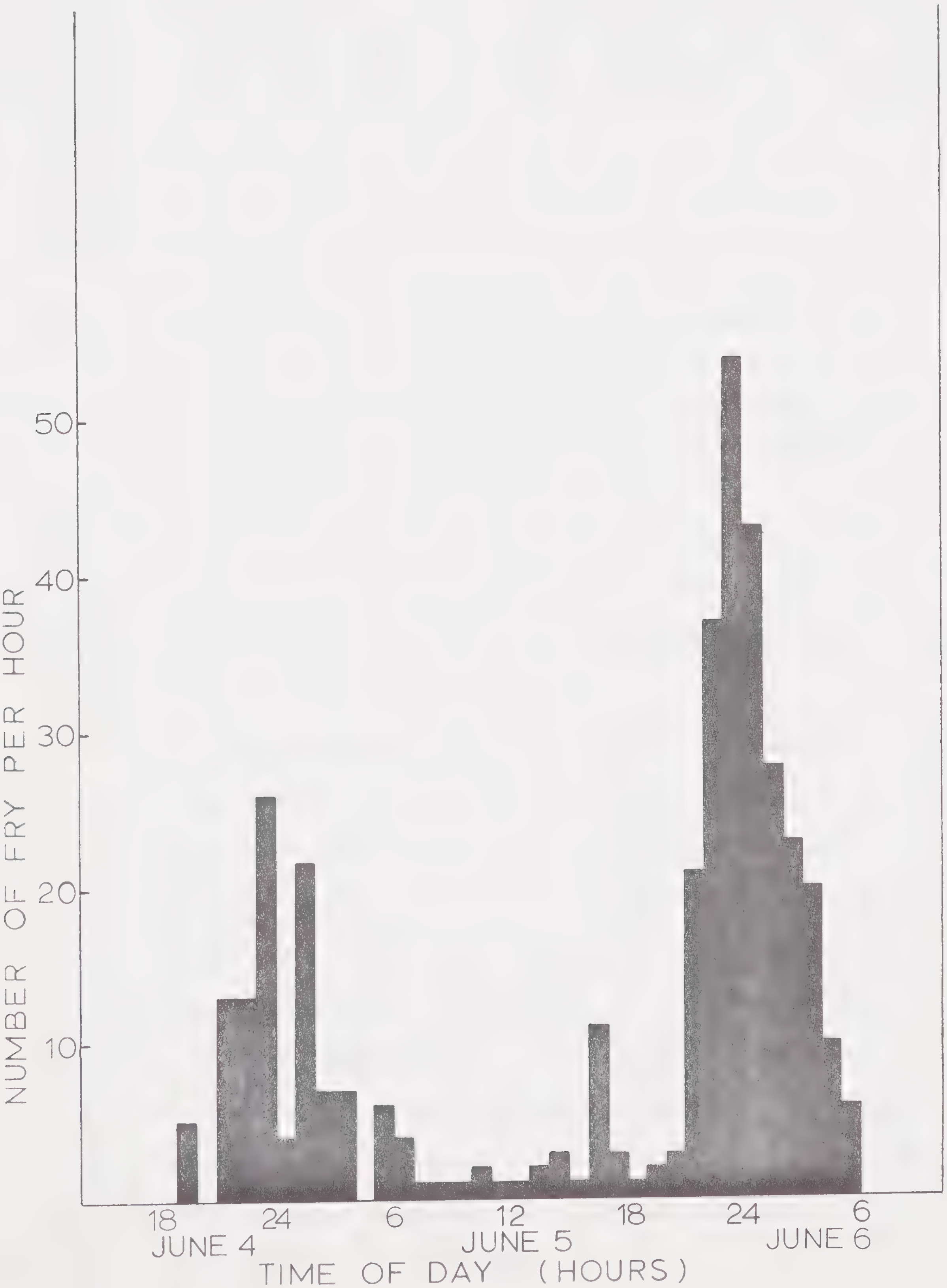
Figure 8a. Unhatched white sucker larvae (8 mm in length) collected from the Bigoray River, May 28, 1969. 5X Magnification.

Figure 8b. A newly hatched white sucker fry (10 mm in length). 5X Magnification.

Figure 9a. White sucker fry, 12 mm in total length, caught on first night of downstream migration, June 4, 1969. $5\frac{1}{2}$X Magnification.

Figure 9b. White sucker fry, 13 mm in total length, with the yolk sac completely resorbed. $5\frac{1}{2}$X Magnification.

Figure 10. Diel timing of downstream migration of white sucker fry in the Bigoray River, June 4 to June 6, 1969.



NUMBER OF FRY PER HOUR
10
20
30
40
50
18
24
6
12
18
24
6
JUNE 4
JUNE 5
JUNE 6
TIME OF DAY (HOURS)

the night's migration had been reduced. Very few fry were captured between sunrise and sunset.

Similar diel cycles have been described for both white and longnose sucker fry (Geen et al, 1966), pink and chum salmon (Neave, 1955), sockeye and coho salmon (McDonald, 1960), and rainbow trout (Northcote, 1962). In all cases the migration appears to be governed by the fry's response to light and current. In the case of chum salmon fry, Hoar (1953) concluded that:

> "As the light intensity falls, rheostatic responses, which are to a large degree dependent on vision, fail, and these fish pass downstream in shoals. The fact that such mass movements occur during a rather precise period of the night is probably due to the dark adaptation of the eye and a period of night blindness."

That this is also the case with white suckers is suggested by Geen et al (1966); they found that the intensity of the downstream migration was decreased when an artificial light source was introduced a short distance upstream from the trap.

Whether the downstream migration of fish fry in general is passive, and hence dependent solely on the current, or involves active swimming on the part of the young fish has long been a matter of debate. Hubbs and Creaser (1924) believe that a passive downstream movement following hatching is a general rule in many fishes and is probably true for white suckers. Geen (1958) accepts this hypothesis. On the other hand, MacKinnon and Brett (1955) suggest that for pink and chum salmon, the fry assume a more active role. They released salmon fry and current vanes at a given point on a stream and recorded the time it took the fry and vanes to arrive at another point farther downstream. The fry arrived considerably before the vanes.

In my study, no examination was made of the seasonal extent of the fry migration. It seems likely though, that the migration continued at least until the end of June. As mentioned previously, a drift net, left in the stream overnight on June 26, collected more than 900 fry.

Age and Growth

Age and growth studies have formed an important part of fisheries research. A knowledge of the age and rate of growth of a fish is extremely useful in management. It is essential in dealing with problems related to population dynamics and fishery forecasts.

Age determinations are based on seasonal changes in growth rate of various bony structures, such as scales, fin rays and otoliths. Such methods are dependent on the fish growing rapidly during the spring and summer and more slowly in winter. This type of growth results in the so-called "annual rings" on the fishes' hard parts, each annulus representing the completion of one year's growth. Because they are so readily available, scales, instead of fin rays or otoliths, have been most widely used in age determination.

Another important use of scales is in the back calculation of the growth history of the fish. Since the scale increases in size as the fish increases in length, there is a relationship between certain scale dimensions and the length of the fish. Having determined the nature of this relationship, one can calculate the length that a particular fish had attained at the end of each year of its life.

There have been some studies on the age and growth of white suckers (eg. Spoor, 1938; Pellock, 1952), but, by and large, the age and growth features of the white sucker have received much less attention than those of other species. This section reports the results of an age and growth study of the white sucker based on 166 specimens taken from the Bigoray River between October, 1968 and November, 1969. It includes a separate discussion of first year growth based on 1095 specimens of the 1969 year class.

Validity of the Annulus as a Year Mark

The scales of the white sucker are of the cycloid type. When first formed the typical scale is circular; but by the time the fish is age two, the scale becomes quadrilateral with the dorsal and ventral margins straight and the anterior and posterior margins rounded (Stewart, 1926). Stewart (1926) and Spoor (1938) have discussed the structure of the white sucker scale in detail. These authors agree that one annulus is formed for each year of the fish's life, and that the annulus is characterized by crowding of the circuli and "cutting over." Raney and Webster (1942) and Rawson (1951) were also able to age white suckers by the scale method.

Other workers, however, have doubted the validity of the annulus as a year mark for the white sucker. Ovchynnyk (1965) and Coble (1967) concluded that an annulus was not formed for each year. Geen _et al_ (1966) suggested that resorption of the periphery of the scale may diminish its value for determining ages of older fish. Beamish and Harvey (1969) stated that scales have little value in determining the ages of older white suckers, and scale ages should be verified by some other technique.

I used the scale method for age determination, although the method did present some difficulties. Raney and Webster (1942) found the first annulus to be indistinct and this was also true in my study. The possibility of overlooking this annulus was minimized by examining numerous scales of young fish. Scale ages were determined for fish up to age 9 without too much difficulty. For fish older than this I consider the validity of the scale method doubtful. False spawning checks were frequent and often made determination of the annulus very difficult. Also,

in some cases, I believe that an annulus was not formed every year. In such cases, otoliths were found useful in determining the age of the fish. For the 17 fish older than 9 years, the age was determined both from otoliths and scales; and when there was a discrepancy between the two methods the otolith age was accepted as the true age.

Body Length-Scale Diameter Relationship

The body-scale relationship was determined using 129 scale samples from fish ranging from 32 to 472 mm in fork length. A scatter diagram of body-scale data indicated a curvilinear relationship (Fig. 11). Because the data were plotted as a straight line on double log paper, the power equation

$$L = aS^{n}$$

was used to describe the relationship. The mathematical relationship between fork length and dorso-ventral scale diameter was found to be

$$L = -1.65859S^{0.76083}$$

This equation in its logarithmic form becomes

$$\log L = 0.81862 + 0.76083 \log S$$

Spoor (1938) and Pellock (1952) assumed the body-scale relationship to be a straight line on an arithmetic scale for all scale diameters and fish lengths. On this basis they back calculated lengths by the direct proportion method. This method assumes that the body-scale ratio remains constant throughout the life of the fish. In my study, however, the body-scale ratio was not constant; instead the ratio decreased as fish length increased (Table VI). The most rapid change in the ratio occurred

Figure 11. Relationship between fork length and dorso-ventral scale diameter.

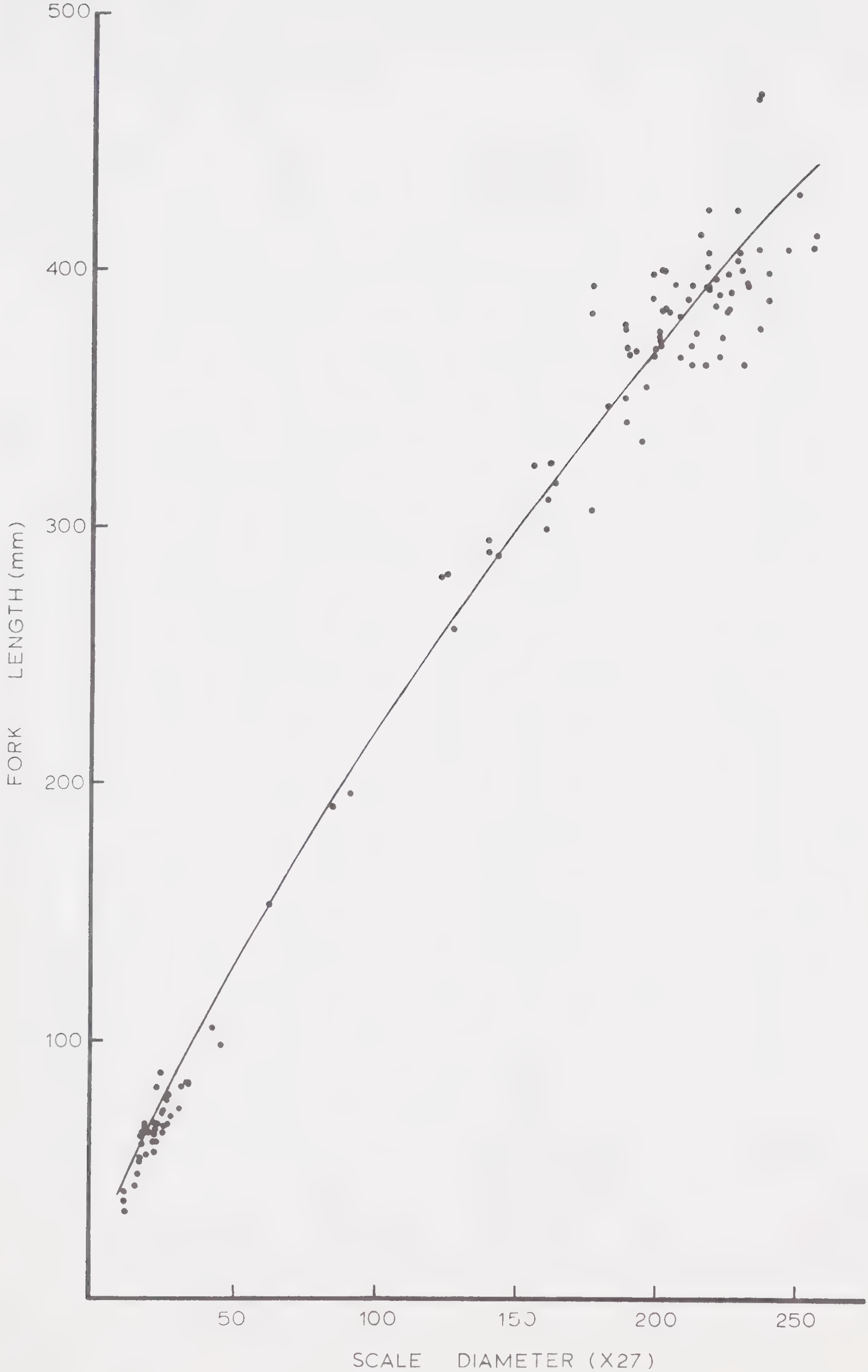

500
400
300
200
100
FORK LENGTH (mm)
50
100
150
200
250
SCALE DIAMETER (X27)

Table VI. Relationship between fork length (L) and dorso-ventral scale diameter (Sc).

Interval of Fork Length (mm)	Number of Fish	Average Scale Diameter (mm X 27)	Average L/Sc Ratio
26-50	6	12.1	3.36
51-75	27	21.5	3.04
76-100	9	30.9	2.79
101-125	1	42.0	2.50
126-150	-	-	-
151-175	1	62.0	2.44
176-200	2	88.5	2.13
201-225	-	-	-
226-250	-	-	-
251-275	1	128.0	2.05
276-300	6	137.8	2.12
301-325	4	163.8	1.93
326-350	4	180.0	1.89
351-375	15	201.7	1.83
376-400	35	209.7	1.86
401-425	15	223.1	1.84
426-450	1	247.0	1.74
451-475	2	234.5	2.01

between the lengths of 30 and 150 mm, indicating that the scales of small fish were relatively smaller than those of larger fish. For fish longer than 300 mm the body-scale ratio was almost constant.

Growth in Length

Figure 12 shows empirical mean fork lengths for white suckers of each scale age (data from Table VII). It is apparent that several age groups are poorly represented. Fish of age III, IV and VI are represented by only 3, 4 and 4 specimens respectively. No age V fish were captured. Because certain age groups are poorly represented, the discussion of growth in length is based largely on the back calculations.

One hundred and nineteen white suckers were used in back calculating growth histories. For each fish, the fork length at each annulus was calculated by substituting scale measurements in the body-scale equation. The mean calculated fork lengths for each age group are shown in Table VIII. For fish of age IV through age X, the calculated lengths approximated the corresponding actual lengths fairly closely. For fish of age I, II, and III, however, the actual lengths are somewhat smaller than the calculated lengths. Two factors may be responsible for this. Firstly, about half the fish of the first three age groups were captured in October and were credited with one more annulus than actually occurred on their scales. This was done because other workers have concluded that the year's growth in white suckers is virtually complete by October (Stewart, 1926 and Spoor, 1938). A second and more probable explanation is that fish of the first three age groups were Bigoray River residents while most of the spawners had likely spent their first three years in the Pembina River. It is not likely that white suckers grow at the same rate in both streams.

Figure 12. Mean growth in fork length as plotted from the empirical data of Table VII. Vertical lines represent range in length within each age group.

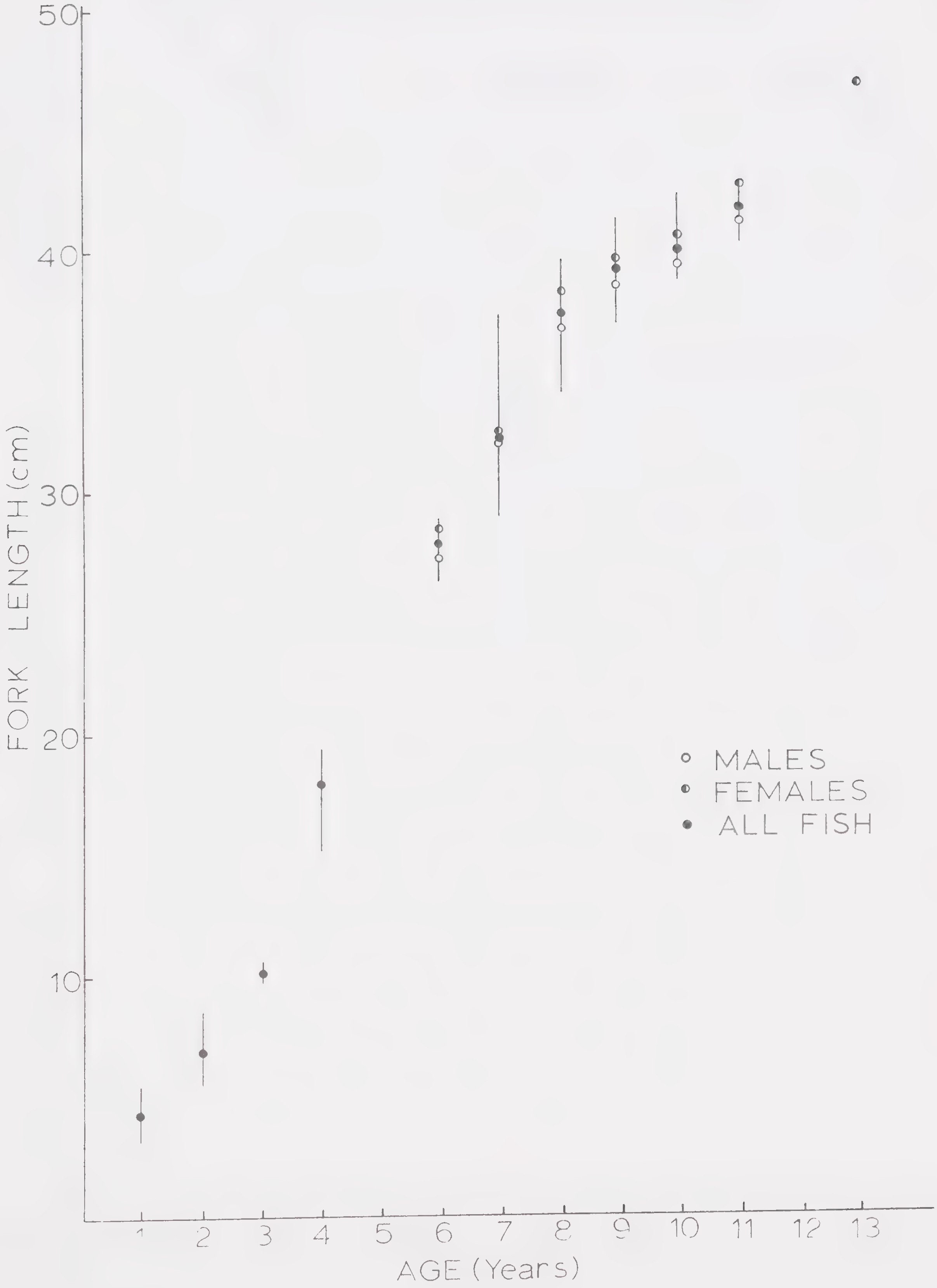

50
40
30
20
10
FORK LENGTH (cm)
MALES
FEMALES
ALL FISH
1
2
3
4
5
6
7
8
9
10
11
12
13
AGE (Years)

Table VII. Mean empirical fork lengths for white suckers of different scale age. (Number of specimens in parenthesis.)

Age	Males	Females	All Fish
I			42.2 (13)
II			68.0 (33)
III			101.3 (3)
IV			180.3 (3)
V	-	-	-
VI	273.0 (2)	286.0 (2)	279.5 (4)
VII	322.4 (5)	327.6 (7)	325.3 (12)
VIII	369.1 (19)	384.8 (13)	375.4 (32)
IX	389.0 (8)	399.4 (13)	395.5 (21)
X	396.0 (6)	407.3 (6)	401.7 (12)
XI	415.0 (2)	430.0 (1)	420.0 (3)
XII	-	-	-
XIII	-	471.0 (2)	471.0 (2)

The calculated data (Table VIII) indicate that white suckers grew at an almost constant rate during their first seven years. After age seven the rate of increase in length decreased although the fish continued to grow.

Table IX compares the calculated lengths of Bigoray River suckers with the calculated lengths of white suckers from other studies. The data of other workers were obtained from Carlander (1950) and Pellock (1952). For purposes of comparison, fork lengths of Bigoray River suckers were converted to total lengths using conversion factors given by Carlander (1950). Bigoray River white suckers appear to grow more slowly than do those from other regions. This is possibly due to the relatively short growing season at this latitude. Another possible explanation is that the other studies dealt with lake populations, whereas my study involved river-inhabiting fish. Perhaps temperature and food supply differences between lakes and streams may account for the differences in growth rates.

While white suckers of the Bigoray River grow slowly, they may live longer than those in other areas. Pellock (1952) found the oldest suckers in Loch Alpine, Minnesota, to be 8 years. Spoor (1938) reported an age 10 white sucker from Muskellunge Lake in Wisconsin. Rawson (1951) found a life span in excess of 12 years for white suckers in Great Slave Lake. In the Bigoray River, two age 13 white suckers were taken. Both were females and they had reached fork lengths of 470 and 472 mm. Of 15 other suckers older than 9 years, eight were males and seven were females.

Other workers have reported that female white suckers are generally longer than males of the same age. Spoor (1938) and Pellock (1952) found

Table VIII. Calculated fork lengths (in mm) at each annulus.

Age Group	No. of Fish	Actual Mean Fork Length for Age Class (mm)	Mean calculated fork length at each annulus (mm) 1	2	3	4	5	6	7	8	9	10	11	12
I		42.2	-											
II	32	68.0	47.4											
III	2	101.3	63.1	92.0										
IV	3	180.3	55.8	87.4	139.5									
V	-	-	-	-	-									
VI	4	279.5	60.7	99.9	139.1	193.6	237.3							
VII	12	325.3	57.4	96.0	135.9	183.3	234.2	283.2						
VIII	29	375.4	56.0	98.2	138.5	180.7	234.4	293.7	343.9					
IX	20	395.5	50.3	96.0	141.4	182.5	226.7	285.1	333.4	367.8				
X	12	401.7	53.2	102.2	148.5	196.0	243.3	303.0	338.9	369.0	393.3			
XI	3	420.0	55.1	88.2	132.3	173.4	217.4	301.2	328.6	369.9	391.9	407.4		
XII	-	-	-	-	-	-	-	-	-	-	-	-	-	
XIII	2	471.0	49.0	84.3	122.2	174.1	223.9	282.0	315.2	348.2	375.9	396.8	406.4	413.3
Grand mean calculated fork length (mm)			52.7 (119)	96.8 (87)	139.7 (85)	184.0 (82)	233.1 (82)	291.3 (78)	338.2 (66)	367.3 (37)	391.0 (17)	403.2 (5)	406.4 (2)	413.3 (2)
Increment of mean			52.7	44.1	42.9	44.3	49.1	58.2	46.9	29.1	23.7	12.2	3.2	6.9

Table IX. Comparison of calculated total lengths obtained by various authors for white suckers.

Reference	Average Calculated Total Length (mm) at Each Annulus.											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Minnesota Eddy & Carlander, 1942	81.3	111.8	210.8	297.2	358.1	406.4	431.8	444.5				
Minnesota Kuehn, 1949	94.0	180.3	259.1	332.7	378.5	424.2	459.7	495.3				
Minnesota Smith & Moe, 1944	109.2	205.7	294.6	353.1	401.3	424.2	436.9	490.2				
Ohio Roach, 1948	63.5	228.6	317.5	383.5	431.8	457.2	469.9	-				
Wisconsin Spoor, 1938	71.1	119.4	162.6	203.2	231.1	261.6	287.0	307.3				
Michigan Pellock, 1952	63.5	149.9	218.4	266.7	307.3	315.0	345.4	-				
Alberta Present Study	54.5	100.2	147.2	194.0	247.9	309.8	363.0	394.2	419.7	432.7	436.2	443.6

females to exceed the males in length from age V on. Mean calculated fork lengths for my study indicate only slight differences in length between male and female suckers of the same age, (Table X), the females being slightly larger from age VII on. My empirical length data (Table VII) indicate a greater length difference between male and female white suckers of the same age, which became apparent at age VI. No age V suckers were captured during this study.

The growth histories of each year class are shown in Figure 13. This figure was constructed using the calculated data shown in Table VIII. Growth appears to have been fairly uniform for all year classes. However, the 1960 year class seems to be composed of fish having a slightly larger size than those of other year classes. This is especially evident from age two to age seven in the 1960 year class. Figure 13 appears to confirm that growth in length proceeds at a constant rate through the first 6 or 7 years of life, and then at a reduced rate in later years.

Growth in Weight

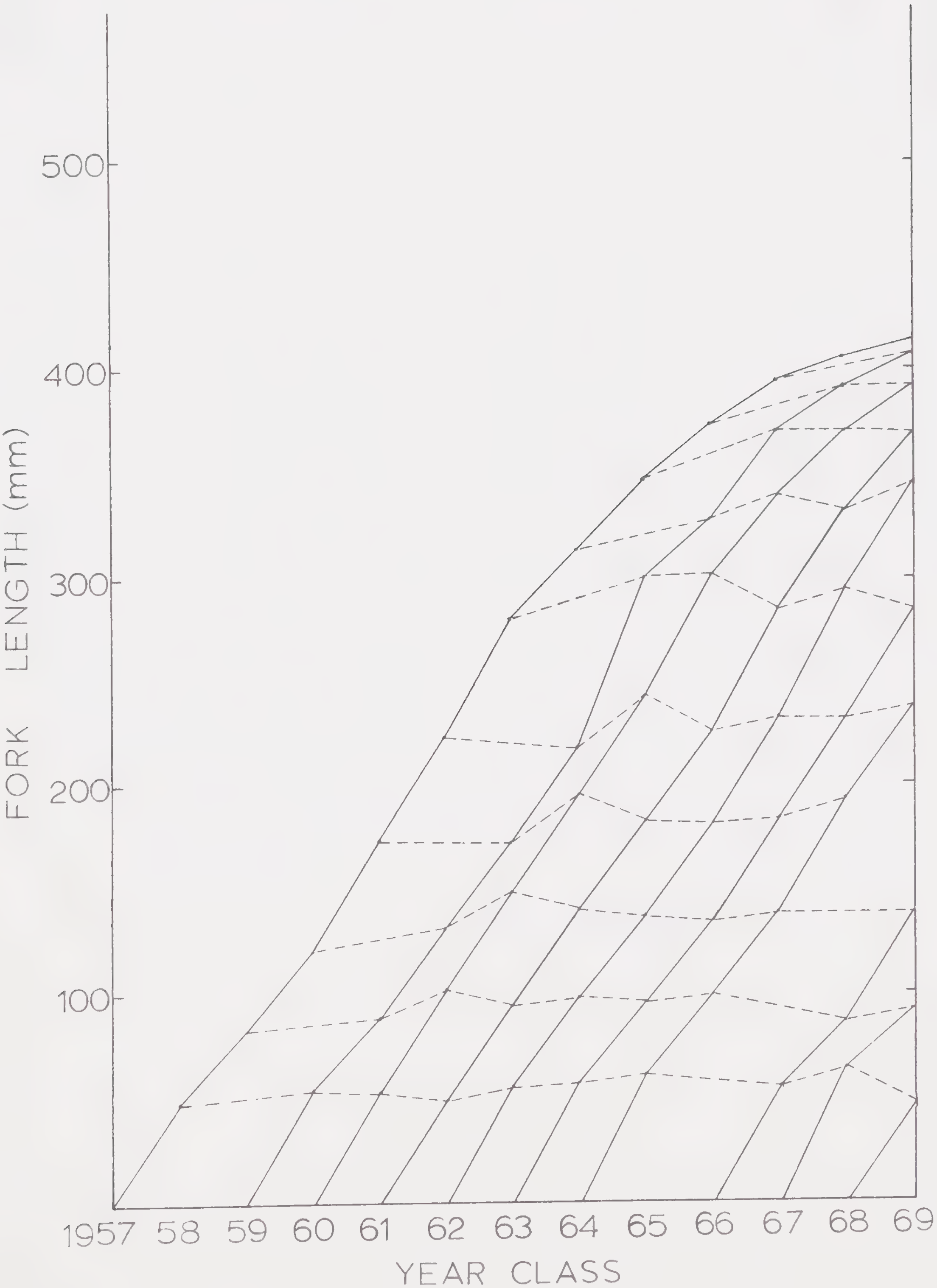
Mean actual weights for fish of each scale age are shown in Table XI and Figure 14. White suckers gained weight very slowly during the first three years of life. A rapid increase then occurred between age III and age VIII. There is some tendency for weight increase to slow down after age VIII.

Weight differences between males and females were more pronounced than were the length differences between the sexes. For white suckers of the same scale age, females were considerably heavier than males. This sexual difference probably developed before age VI but no age five fish were collected. For age groups VI, VII AND VIII, females out-

Table X. Mean calculated fork lengths (in mm) at each annulus for male and female white suckers. (Number of specimens in parenthesis.)

Age	Males		Females		All Fish	
I					52.7	(119)
II					96.8	(87)
III					139.7	(85)
IV	182.4	(38)	183.4	(44)	184.0	(82)
V	236.4	(38)	230.2	(44)	233.1	(82)
VI	294.8	(36)	288.1	(42)	291.3	(78)
VII	336.4	(32)	340.0	(34)	338.2	(66)
VIII	364.6	(15)	369.2	(22)	367.3	(37)
IX	384.8	(8)	396.5	(9)	391.0	(17)
X	400.8	(2)	404.8	(3)	403.2	(5)
XI	-		406.4	(2)	406.4	(2)
XII	-		413.3	(2)	413.3	(2)

Figure 13. Growth histories of the different year classes. (Data from Table VIII). Lengths at corresponding years of life are connected by dashes.

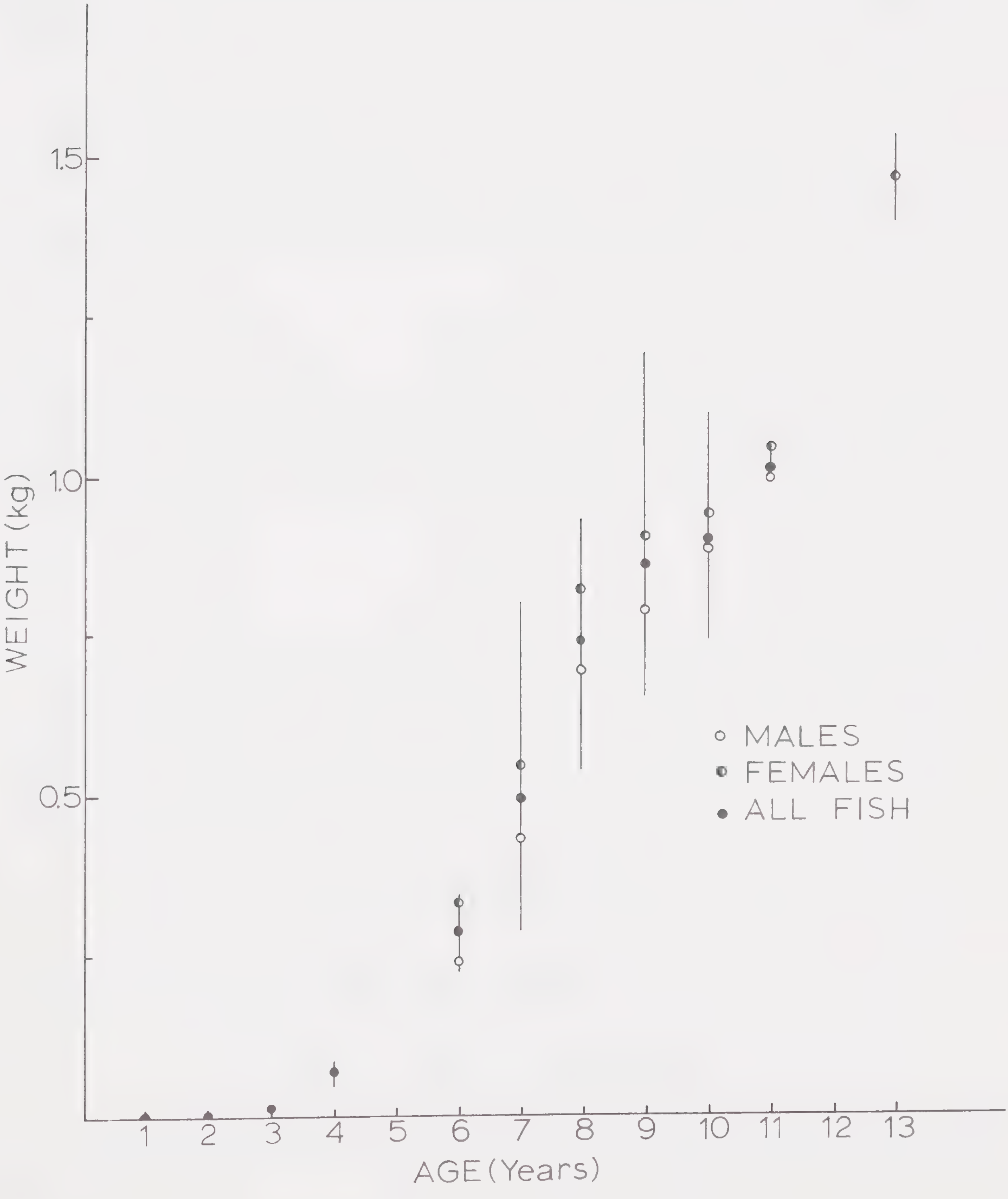


FORK LENGTH (mm)
500
400
300
200
100
1957
58
59
60
61
62
63
64
65
66
67
68
69
YEAR CLASS

Table XI. Mean empirical weights for white suckers of different scale ages. (Number of specimens in parenthesis.)

Age	Males		Females		All Fish	
I					0.89	(13)
II					3.81	(33)
III					13.10	(3)
IV					71.20	(3)
V	-		-		-	
VI	241.0	(2)	331.2	(2)	287.1	(4)
VII	430.9	(5)	536.6	(7)	492.6	(12)
VIII	688.6	(19)	827.6	(13)	745.1	(32)
IX	790.3	(8)	910.5	(13)	864.7	(21)
X	882.9	(6)	940.3	(6)	902.5	(12)
XI	994.2	(2)	1049.0	(1)	1015.9	(3)
XII	-		-		-	
XIII	-		1474.2	(2)	1474.2	(2)

Figure 14. Growth in weight as plotted from the empirical data in Table XI. Vertical lines represent range in weight within each age group.



1.5
1.0
0.5
WEIGHT (kg)
1
2
3
4
5
6
7
8
9
10
11
12
13
AGE (Years)
MALES
FEMALES
ALL FISH

weighed the males by 90.2, 105.7 and 139.0 grams respectively.

Part of the weight differences between the sexes might be due to mature fish being captured only during the spawning season. Nevertheless, the tendency for female white suckers to outweigh males of the same age has been reported by other workers regardless of the time of year.

Length-Weight Relationship

The mathematical relationship between fork length and body weight was determined by fitting the general power equation

$$W = aL^n$$

to the empirical length and weight data without grouping. Hile (1936) believes that the general power equation better expresses the length-weight relationship than does the more specific cubic parabola

$$W = aL^3$$

The arithmetic length-weight relationship for Bigoray River suckers is shown in Figure 15. When these data are fitted to the general power equation, the mathematical expression that best describes the length-weight relationship is

$$W = 7.66266 \times 10^{-6} L^{3.10052}$$

which in its log form (Figure 16) becomes

$$\log_e W = -11.77915 + 3.10052 \log_e L.$$

Since n is 3.10052, Bigoray River white suckers apparently increase

Figure 15. Length-weight relationship for Bigoray River white suckers.

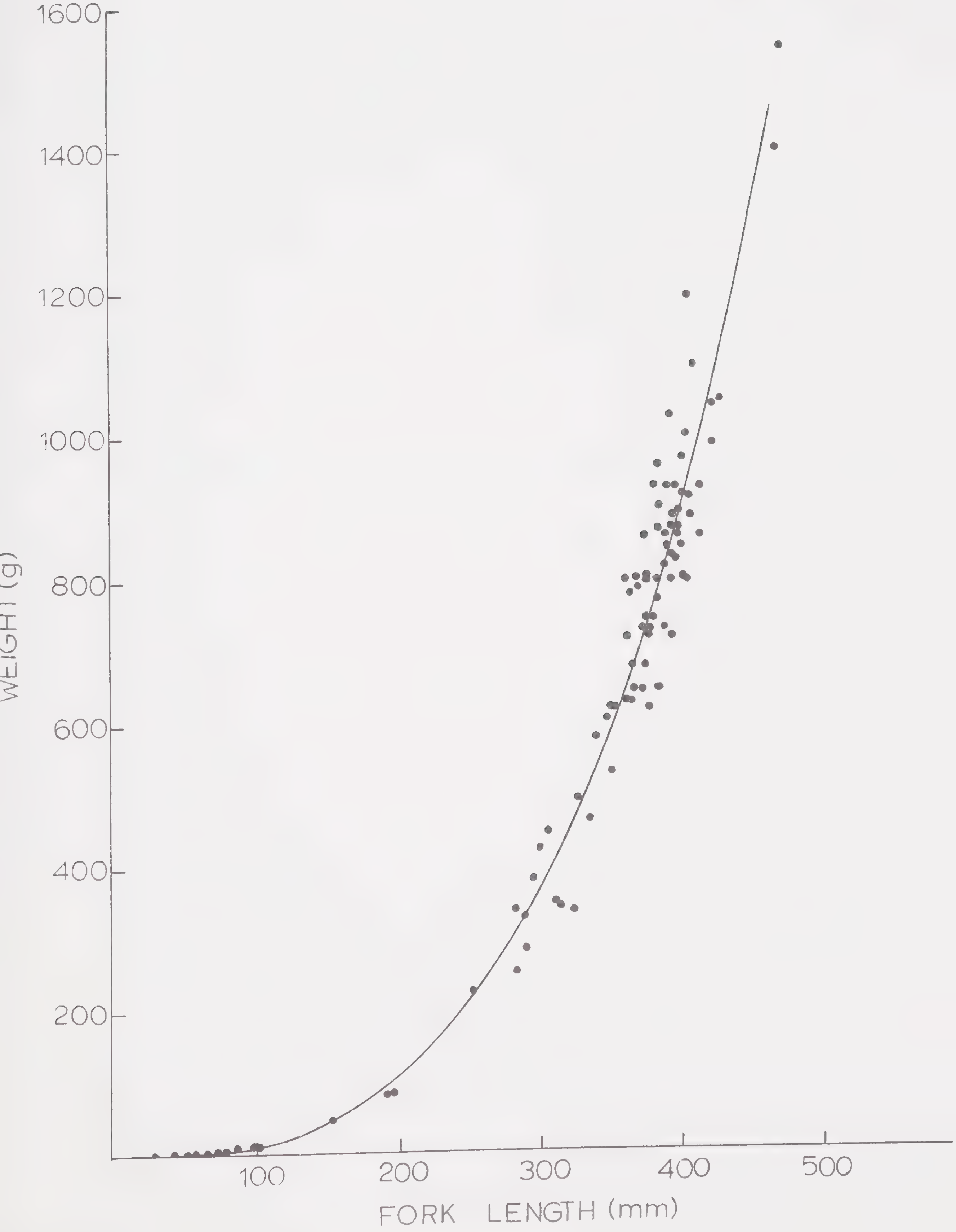

1600
1400
1200
1000
800
600
400
200
WEIGHT (g)
100
200
300
400
500
FORK LENGTH (mm)

Figure 16. Length-weight relationship for Bigoray River white suckers plotted on a logarithmic scale.

WEIGHT (g)
1000
100
10
1
0.1
1
10
100
1000
FORK LENGTH (mm)

in weight slightly faster than the cube of the length (n = 3.0). Spoor (1938) found white suckers to increase in weight as the cube of the length over a range of 115 to 300 mm (standard length). Coble (1967) calculated n to be 2.92262 for white suckers in Lake Huron during the month of June.

The validity of my length-weight equation is confirmed by how closely the calculated weights approximate the actual weights (Table XII). These data show the deviations between actual and calculated weights to increase slightly with increasing length of fish, but generally these deviations are slight.

First Year Growth

Information on the early growth of white suckers was obtained from weekly samples taken between June 1 and August 1, 1969. The availability of young fish declined throughout the summer because of their downstream migration and removal by floods. There was a large decline in the number of young fish following a flood on July 10, and young fish became very scarce in the study area after a second flood, occurring on August 6 (Figs. 17a and 17b).

Growth in length appears to be curvilinear during the first summer (Fig. 18). Between June 1 and July 3 the young fish increased in length at a steady rate, but relatively slower than the rate observed during the remainder of July and early August.

Growth in length was probably more linear than is indicated by Figure 18. Hatching began on or about May 28, and is assumed to have continued for two to three weeks after this date (i.e. until about June 11 to 18). Since the newly hatched fish remain in the gravel for one to two weeks, one might expect the influx of young fish to continue

Table XII. Comparison of actual and calculated mean weights.

Length Interval (mm	Number of Fish	Actual Mean Length (mm)	Actual Mean Weight (g)	Calculated Mean Weight (g)	Deviation from Actual Mean (g)
26-50	16	42.9	0.9	1.0	+0.1
51-75	50	63.6	3.2	3.1	-0.1
76-100	9	82.8	6.9	7.1	+0.2
101-125	2	103.0	13.8	13.4	-0.4
126-150	-	-	-	-	-
151-175	1	153.0	47.2	45.5	-1.7
176-200	2	194.0	83.2	95.1	+11.9
201-225	-	-	-	-	-
226-250	-	-	-	-	-
251-275	1	262.0	226.8	241.2	+14.4
276-300	6	290.5	335.5	332.7	-2.8
301-325	4	314.8	428.8	426.6	-2.2
326-350	4	338.5	538.7	534.6	-4.1
351-375	16	365.9	709.7	680.6	-29.1
376-400	37	388.7	818.3	820.5	+2.2
401-425	15	409.0	943.1	960.6	+17.5
426-450	1	430.0	1049.0	1120.7	+71.7
451-475	2	471.0	1474.2	1486.4	+12.2

Figure 17a. Photograph of the Bigoray River during low water, August 1, 1969.

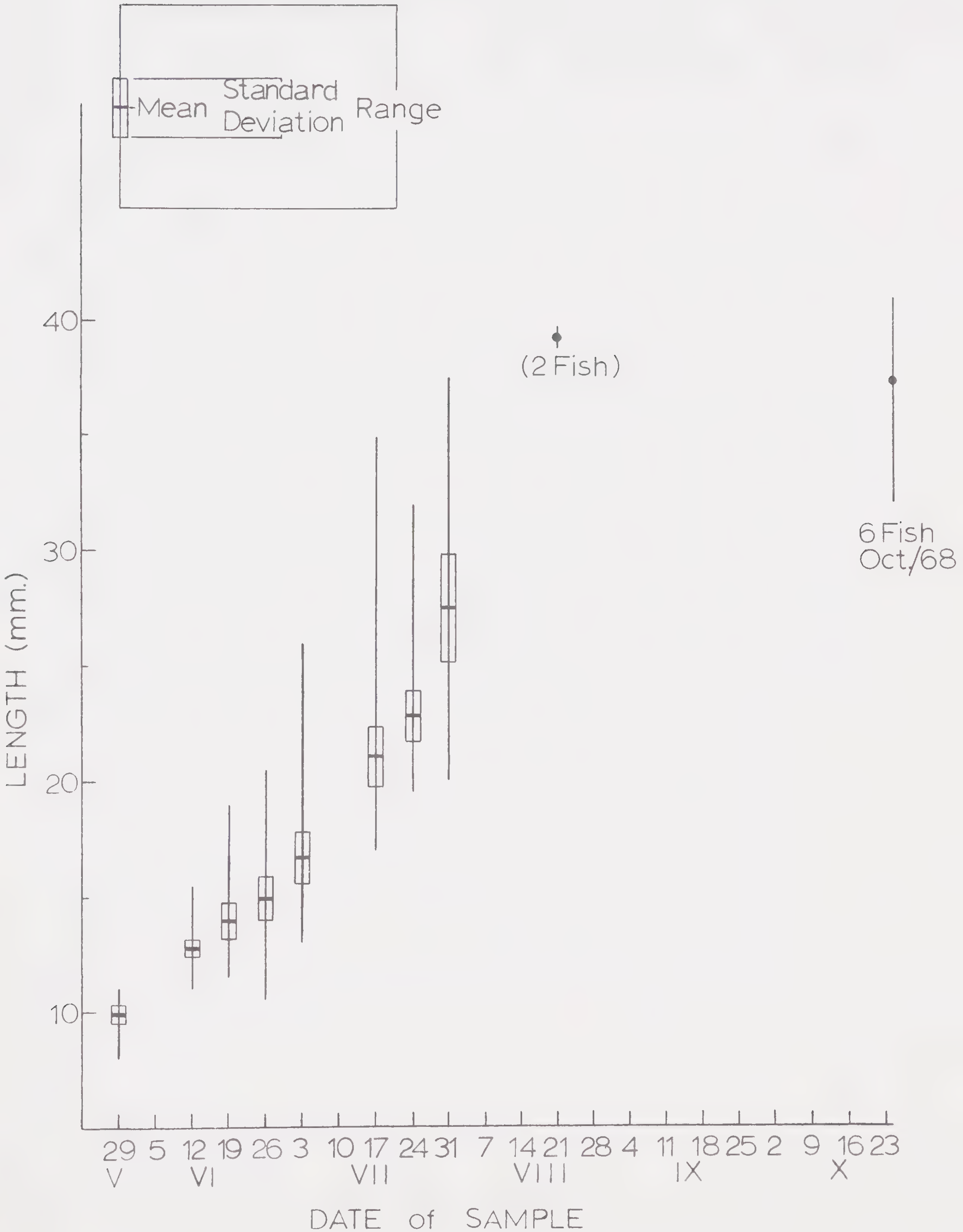
Figure 17b. Photograph of the Bigoray River at the height of the flood, August 6, 1969.

until near the end of June. Obviously the mean lengths of fish from samples taken during this period will be influenced by the steady influx of new fish. That this did occur is suggested by the daily length increment data of Table XIII. The rise in the daily increment after June 26 may indicate that the influx of new fish had ceased.

Hubbs and Creaser (1924) noticed the growth rate of first year white suckers slowing up during late summer. Although direct evidence is lacking, it seems probable that the rate of length increase of Bigoray River suckers also decreased at this time. Two fish captured on August 20, 1969, measured 39.0 and 39.5 mm in length, while six first year fish taken in October, 1968, ranged from 32 to 41 mm and averaged 37.3 mm in length. Because the Bigoray River cools off very rapidly after the end of August, it is likely that the growing season is virtually completed by early September. Spoor (1938) concluded that the entire seasonal growth of white suckers is probably completed by mid-September in Muskellunge Lake, Wisconsin. Embody (1915) and Adams and Hankinson (1928) found white suckers to reach a length of 75 to 100 mm by the end of their first season. Bigelow (1923) reported the average length of young suckers in Lake Nipigon, Ontario, to be 40 mm by mid-August. In Douglas Lake, Michigan, Hubbs and Creaser (1924) found first year white suckers to be as long as 51 mm in mid-August. Stewart (1926) states that suckers in the vicinity of Ithaca, New York, reach a length of 38 mm by the end of their first season.

Six white suckers taken from the Bigoray River in October, 1968 averaged 37.3 mm in length. Seven white suckers captured early in the spring of 1969 ranged from 37 to 56 mm in length and averaged 46.1 millimeters. The 13 fish combined, ranged from 31 to 56 mm and had

Figure 18. Growth in length of first year white suckers from the Bigoray River.



Mean
Standard Deviation
Range
LENGTH (mm.)
40
30
20
10
(2 Fish)
6 Fish Oct/68
29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23
V
VI
VII
VIII
IX
X
DATE of SAMPLE

an average length of 42.2 millimeters. Assuming 42.2 mm as the average maximum length attained by first year white suckers in the Bigoray River, suckers of the 1969 year class had completed 30.3% of their year's growth by June 12; 35.4% by June 26; 50.0% by July 17; 65.4% by August 1; and 93.0% by August 20. (Table XIII).

Growth in weight of first year white suckers is plotted on a semi-log scale in Figure 19. During the first few weeks of life, the fish gained very little in weight, although they did increase considerably in length. After the first few weeks, however, the rate of weight increase greatly exceeded the rate of length increase.

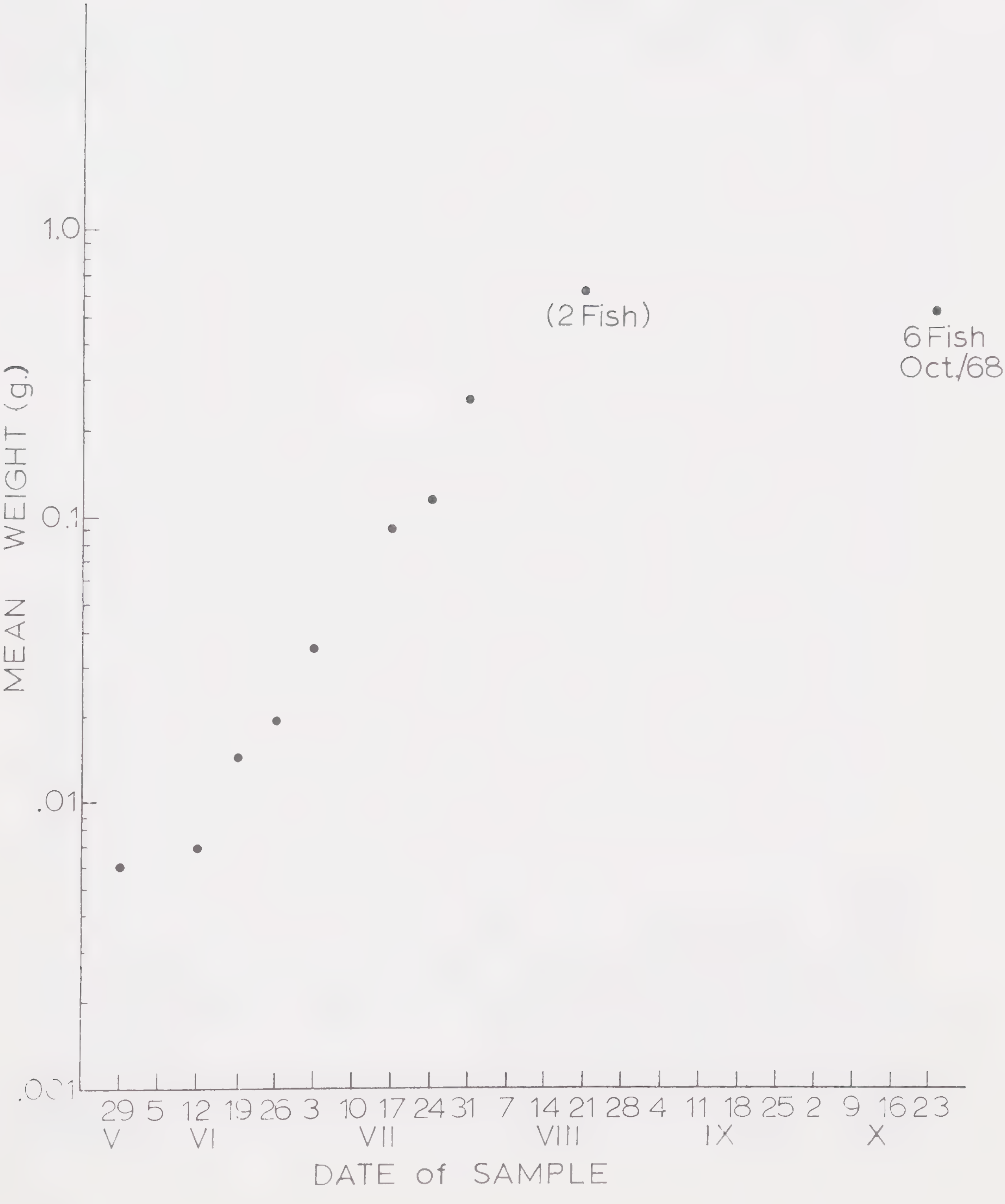
Presumably growth in weight, like growth in length, slows up toward the end of August but here again direct evidence is lacking. Six fish collected in October, 1968, had a mean weight of 0.53 grams. Seven fish taken in early spring, 1969, averaged 1.2 grams. The average weight for these 13 fish was 0.89 grams. Hence, by the end of their first growing season, Bigoray River white suckers had a mean length of 42.2 mm and a mean weight of 0.89 grams.

Table XIII. Summary of growth of young-of-the-year white suckers from the Bigoray River.

Collection Date	Fish (no.)	Mean L (mm)	Range of L (mm)	S.Dev.	Mean Wt. (g)	Per Diem Length Increment (mm)	% Growth * Completed
May 29/69	50	9.98	8.0-11.0	0.80	0.0060	-	-
June 12	50	12.80	11.0-15.5	0.74	0.0070	0.256	30.3
20	100	13.99	11.5-19.0	1.59	0.0141	0.149	33.1
26	160	14.93	10.5-20.5	1.89	0.0195	0.157	35.4
July 3	310	16.73	13.0-26.0	2.21	0.0359	0.257	39.6
17	192	21.11	17.0-35.0	2.57	0.0941	0.313	50.0
24	180	22.87	19.5-32.0	2.25	0.1245	0.251	54.2
Aug. 1	53	27.58	20.0-37.5	4.60	0.2687	0.673	65.4
20	2	39.25	39.0-39.5		0.65	0.614	93.0

* % Growth completed is based on expected mean Length of 42.2 mm. (Derived from 1968 year class).

Figure 19. Growth in weight of first year white suckers from the Bigoray River.



MEAN WEIGHT (g.)
1.0
0.1
.01
.001
(2 Fish)
6 Fish
Oct./68
29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23
V VI VII VIII IX X
DATE of SAMPLE

Food Habits

The feeding habits or feeding behaviour of fishes, in the strictest sense, are the search for and ingestion of food. These phenomena should be distinguished from food habits and diet, which are the materials habitually or fortuitously eaten (Lagler et al, 1962). Only food habits and diet are treated in this study.

A fish eats those types of food to which it is adapted. Nikolsky (1963) divided the food of fishes into three categories:

(1) Basic food--that which the fish usually consumes, comprising the main part of the gut contents.

(2) Secondary food--frequently found in the gut but in smaller amounts.

(3) Incidental food--only rarely found in the gut.

Such a classification is of limited value. The basic food of any fish species must change throughout the year according to the abundance of the prey species, which, in turn, fluctuates as a result of factors associated with environmental conditions and the prey species' life history. As well, a fish, by virtue of its size, is limited in the variety of food items it can ingest; i.e., a small fish must subsist on small prey organisms, the presence of a large population of larger organisms being of no significance.

Much valuable food habit information has been obtained by examination of stomach contents. Such data, however, show only what a fish will eat and shed no light on the intricacy of the relationship between the predator and the prey species. The value of such studies would be greatly enhanced if the data were accompanied by information concerning

the kinds and relative numbers of food organisms present (Hess and Schwartz, 1940).

The aim of my study was to assess the food habits of white suckers and to relate the diet of the fish to the invertebrate fauna of the Bigoray River. A serious omission of the study was the failure to consider the microscopic fauna of the stream. As will be seen later, small crustaceans and rotifers comprise a major portion of the food of young suckers. This study is based on examinations of stomach contents of 354 white suckers and on bottom fauna collections taken between October 1, 1968 and December 1, 1969.

Composition of the Diet

White suckers in the Bigoray River consumed a great variety of benthic and planktonic organisms. Small suckers fed mainly on chironomid larvae, small Crustacea, rotifers, diatoms and desmids. Adult suckers relied chiefly on immature insects. Table XIV indicates the diversity of food organisms utilized by white suckers. In all, 57 taxonomic groups of food organisms were identified from 319 sucker stomachs. The number of taxa is minimal since several groups could only be identified to family or order.

The food of Immature Suckers

The stomach contents of 267 immature suckers were examined. These fish ranged in length from 11.5 to 196.0 mm, but only six fish exceeded 90.0 millimeters. All but two of these fish had food in their stomachs.

The major dietary items for immature white suckers are summarized in Table XV. In terms of numbers, immature insects accounted for about half (50.5%) of the total diet. Small crustaceans contributed 35.9%

Table XIV. List of food organisms found in the stomachs of 319 white suckers from the Bigoray River.

CHLOROPHYTA
- *Microspora* *spp*.
- *Closterium* *sp*.
- *Closteriopsis* *sp*.
- *Closteridium* *sp*.
- *Crucigenia* *sp*.

CHRYSOPHYTA
- *Fragilaria* *sp*.
- *Stephanodiscus* *sp*.
- *Synedra* *sp*.
- *Cymbella* *sp*.
- *Nitzschia* *sp*.
- *Navicula* *sp*.

ROTIFERA
- *Keratella* *sp*.
- *Monostyla* *sp*.
- *Trichotria* *sp*.
- *Cephalodella* *sp*.
- *Testudinella* *sp*.
- *Brachionus* *sp*.
- *Notholca* *sp*.
- *Colurella* *sp*.

TARDIGRADA
- 1 specimen

CRUSTACEA
- Cladocera
  - *Acroperus* *harpae* Baird
  - *Chydorus* *sp*.
  - *Graptoleberis* *testudinaria* (Fischer)
- Copepoda (probably *Cyclops*)
- Ostracoda
- Amphipoda
  - *Hyalella* *azteca* (Saussure)
  - *Gammarus* *lacustris* Sars

HYDRACARINA

INSECTA
- Plecoptera
  - *Nemoura* *cinctipes* Banks
- Ephemeroptera
  - *Baetis* *tricaudatus* Dodds
  - *Callibaetis* *coloradensis* Banks
  - *Caenis* *simulans* McD.
  - *Stenonema* *sp*.
  - *Siphloplecton* *basale*
  - *Leptophlebia* *cupida* (Say)
- Odonata
  - *Aesøhna* *subarctica* Walker
- Hemiptera
  - Corixidae
- Trichoptera
  - *Hydropsyche* *slossonae* Banks
  - *Hydropsyche* *recurvata*
  - *Cheumatopsyche* *analis* Banks
  - *Oecetis* *sp*.
  - *Brachycentrus* *americanus* Banks
  - *Limnephilus* *spp*.
  - *Agraylea* *sp*.
  - Hydroptilidae
- Coleoptera
  - Elmidae
  - Dytiscidae
    - Dytiscinae
    - Hydroporinae
  - Haliplidae
- Diptera
  - Chironomidae
  - Simuliidae
  - Tipulidae
    - *Tipula* *sp*.
    - *Dicranota* *montana* Alex.
  - Tabanidae
    - *Chrysops* *sp*.
- Megaloptera
  - *Sialis* *cornuta* Ross

GASTROPODA
- *Helisoma* *sp*.

PELECYPODA
- Sphaeriidae

Table XV. Percent frequency of occurrence and percent number of the major food items in the diet of immature white suckers.

Food Item	Percent Occurrence	Percent Number
INSECTA		
Chironomidae	92.9	32.9
Simuliidae	40.8	6.2
Baetis tricaudatus	47.6	10.7
Other Insecta	14.2	0.7
CRUSTACEA		
Ostracoda	66.3	20.7
Copepoda (Adults)	60.7	9.9
Copepoda (Nauplii)	26.2	2.9
Cladocera	40.8	2.4
ROTIFERA	33.0	13.4
DIATOMS	52.4	-
DESMIDS	56.9	-
OTHERS	1.5	0.1

and rotifers made up 13.4% of the food.

Only three groups of insects were important in the food of immature fish. Larval chironomids were found in 92.9% of all stomachs and accounted for 65.1% of the insect food. Larvae of Simuliidae had a frequency of 40.8% and made up 12.3% of the total insect food. *Baetis* nymphs occurred in 47.6% of the stomachs and comprised 21.2% of all insects eaten. Other insects eaten by the small suckers included *Nemoura cinctipes*, *Leptophlebia cupida*, *Aeschna subarctica*, Corixidae, Hydropsychidae, *Oecetis sp.*, *Brachycentrus americanus*, *Agraylea sp.*, Hydroptilidae, Coleopterous larvae, *Chrysops sp.* and *Sialis cornuta*. These insects were eaten in very small amounts, making up less than 1.0% of the total diet.

Of the small Crustacea, ostracods were the most important, occurring in 66.3% of the stomachs and accounting for 57.6% of all crustacean food. Copepods had a high frequency of occurrence but they were eaten in relatively small numbers. Adult copepods comprised 27.6% of the crustacean food but only 9.9% of the total food. The corresponding figures for copepod nauplii were 8.0% and 2.9%. Cladocera had a frequency of 40.8%, but contributed only 2.4% of the total number of food items.

Diatoms and desmids were the most important algae in the diets of young suckers, with frequencies of 52.4% and 56.9% respectively. Various other unicellular algae and small amounts of filamentous algae were often found in the stomach contents, but they contributed very little to the total diet.

Considering their mode of feeding, small suckers consumed surprisingly small amounts of debris. Sand and gravel were rarely found

in the stomach contents.

The food of adult suckers

Of the 87 adult suckers examined, 52 (59.8%) contained food. These fish ranged from 262 to 472 mm in fork length. The major food items of adult white suckers are presented in Table XVI. Adult suckers of the Bigoray River are almost exclusively insectivorous during their spawning migration. Insects accounted for 99.5% of the total food in terms of numbers and 98.0% by wet weight. The remainder of the diet consisted of small numbers of amphipods, molluscs and small crustaceans. The stomachs of many adults contained copious amounts of mucus in which animal and plant debris were mixed. Most of this debris consisted of broken mollusc shells and insect fragments. Vegetable debris was also common, some of which was undoubtedly the remains of limnephilid cases. Sand and gravel were present in small amounts. Filamentous algae was rare and was, presumably, consumed more by accident than by design. Since the stomach contents of adult suckers were not examined at high magnification there is no information on the utilization of unicellular algae by adult fish. In any case such items would be unimportant in terms of biomass.

Diptera larvae, mainly Chironomidae and Simuliidae, formed the major part of the food of adult suckers (Table XVI). Dipterans were found in 98.1% of the stomachs, comprising 81.4% of the total diet by numbers and 47.9% of the total biomass. Simuliidae larvae were the single most important food item, accounting for 59.8% of the total by numbers and 34.0% by wet weight. Other dipterans eaten by adult suckers were the craneflies _Tipula_ _sp._ and _Dicranota_ _montana_ and the tabanid _Chrysops_ _sp._

Table XVI. Percent frequency of occurrence, percent number, and percent wet weight for the major food items in the diet of adult white suckers.

Food Item	Percent Occurrence	Percent Number	Percent Wet Weight
INSECTA			
Ephemeroptera			
Baetis tricaudatus	48.1	13.9	3.8
Leptophlebia cupida	30.8	0.8	6.3
Other Ephemeroptera	7.7	0.6	2.9
Trichoptera			
Hydropsyche spp.	13.5	0.3	5.8
Cheumatopsyche analis	17.3	0.2	1.0
Limnephilidae	11.5	0.2	13.4
Oecetis sp.	36.5	0.6	3.6
Other Trichoptera	13.5	0.3	0.4
Diptera			
Chironomidae (Larvae)	92.3	19.4	9.0
Simuliidae (Larvae)	86.5	59.8	34.0
Other Diptera	50.0	2.2	4.9
Coleoptera			
Adults	19.2	0.5	5.7
Larvae	23.1	0.4	0.8
Megaloptera			
Sialis cornuta	13.5	0.2	3.7
Other Insecta	9.6	0.1	2.7
MOLLUSCA	5.8	0.1	-
AMPHIPODA	9.6	0.2	2.0
SMALL CRUSTACEA	15.4	0.5	-

Ephemeroptera nymphs occurred in 67.3% of the stomachs. They made up 15.3% of the food in terms of numbers and 13.0% of the total wet weight. Baetis tricaudatus was the most abundant mayfly in the stomach contents (13.9%), but its contribution to the total food biomass (3.8%) was relatively small. By contrast, Leptophlebia nymphs were less important numerically (0.8%); but, being larger nymphs, comprised 6.3% of the wet weight. Callibaetis coloradensis, Caenis simulans, Siphlonecton basale and Stenonema sp. were eaten in small quantities.

At least eight genera of Trichoptera were represented in the food. Oecetis sp. was the most common caddis larva in the food, occurring in 36.5% of the stomachs. Trichopterans as a whole made up only 1.6% of the total number of food items; but, because of the large size of certain species, they made up 24.2% of the biomass. Limnephilidae (13.4%), Hydropsyche spp. (5.8%) and Oecetis sp. (3.6%) were the most important trichopterans on a biomass basis. Other caddis larvae eaten by adult white suckers included Cheumatopsyche analis, Brachycentrus americanus, Agraylea sp. and an unidentified hydroptilid.

Collectively, the Coleoptera, Megaloptera, Odonata and Corixidae accounted for 1.2% of the food by numbers and 12.9% by wet weight.

The white sucker has diversified food habits, seeming to feed on anything that is available and capable of ingestion. In the Bigoray River, small suckers fed mainly on chironomid larvae, small Crustacea, rotifers, diatoms and desmids. This is consistent with the findings of Crawford (1923), Stewart (1926) and Dobie (1970). However there are no consistent reports dealing with the food habits of adult suckers. Various workers have found some white sucker stomachs to contain 100% insect food. Others have reported 100% plant material or as much as

95% molluscs (Dobie _et al_, 1948). In a sample of 18 adult fish from Great Slave Lake, Rawson (1951) found the stomach contents to consist of 49% insects, 30% amphipods and 20% molluscs. In general, however, there seems to be agreement that the white sucker is mainly insectivorous. This is certainly the case in the Bigoray River, at least during the spring and summer months.

Dietary changes during the life history of the white sucker

Each fish species is adapted to feeding on a particular type of food. However, feeding adaptations can change as the fish grows. Obviously, what the fish eats will be influenced by the size of the fish. For the white sucker, the position of the mouth also affects the feeding habits. As the mouth changes from a terminal to an inferior position, the sucker loses the ability to subsist on swimming or floating forms and must rely on benthic organisms.

Stewart (1926) recognized five periods in the life history of the white sucker, which he distinguished both by the behaviour of the fish and by analysis of the gut contents. He defined these periods as follows:

(1) _Yolk-food Period_: This period lasts until the commencement of external feeding, or until the fish is about 12 mm in length.

(2) _Top-feeding Period_: During this period the mouth is terminal in position and the fish (from 12 to 16 or 17 mm) feeds at or near the water surface.

(3) _Critical Period_: This term refers to the brief time when the mouth is in the process of shifting from terminal to inferior. The fish are about 16 to 18 mm in length.

(4) _Fingerling Period_: The mouth is now inferior and the fish (18 to 75

mm) is a bottom feeder. The inability of the fish to separate the food from the sand results in a large amount of sand appearing in the alimentary tract.

(5) Adult Period: Fish (longer than 75 mm) are now able to separate the food from the sand. Microorganisms are almost completely eliminated from the diet and the fish feeds almost exclusively on insect and other macroscopic food.

Following Stewart's (1926) outline, I have separated the period of external feeding of the Bigoray River population into 5 stages. Stage I corresponds to Stewart's "Top-feeding Period" and includes fish from 11.5 to 16.5 millimeters. Stage II fish are those between the lengths of 17.0 and 18.5 mm, corresponding to Stewart's "Critical Period." I have divided Stewart's "Fingerling Period" into two stages. Stage III involves fish between the lengths of 19.0 and 40.0 millimeters. Stage IV includes fish from 41.0 to 75.0 millimeters. This division was made because of the change in habitat that occurs at a length of about 40 millimeters. Fish smaller than 40 mm are not strong enough swimmers to withstand the current at midstream, and they are restricted to pools and to moderate currents along the edges of the stream. Fish longer than 40 mm are usually found in faster water. Stage V corresponds to Stewart's "Adult Period."

Frequency of occurrence and percent numbers results for each stage are shown in Table XVII. The diet of young suckers changed very little until the fish were about 40 mm in length; chironomid larvae, ostracods, rotifers, diatoms and desmids dominating the stomach contents during the first three stages. Because of their small size, fish of the first three stages are restricted to microscopic food organisms. The fact

Table XVII. Percent frequency of occurrence and percent number for major food items at five stages in the life history of the white sucker. (No. of fish in parenthesis).

	STAGE I 11.5-16.5 mm. (59)		STAGE II 17.0-18.5 mm. (16)		STAGE III 19.0-40.0 mm. (119)		STAGE IV 41.0-75.0 mm. (57)		STAGE V 75.0 mm. (66)	
	Percent Occur.	Percent Number	Percent Occur.	Percent Number	Percent Occur.	Percent Number	Percent Occur.	Percent Number	Percent Occur.	Percent Number
Chironomid Larvae	100.0	42.2	100.0	34.2	91.6	26.5	84.2	36.6	90.9	22.0
Simuliidae Larvae	35.6	2.3	31.3	1.9	43.7	3.1	50.9	12.1	75.8	50.6
<u>Baetis tricaudatus</u>	23.7	2.4	87.5	7.5	50.4	2.9	56.1	16.0	48.5	18.3
Ostracoda	74.6	25.7	81.3	40.2	68.1	16.6	59.6	24.1	16.7	2.3
Copepoda (Adults)	44.1	3.2	68.7	7.1	74.8	12.8	50.9	8.0	15.2	2.0
Copepoda (Nauplii)	20.3	1.3	25.0	0.9	35.3	5.3	17.5	1.1	4.6	0.1
Cladocera	32.2	2.3	68.7	4.5	56.3	3.2	12.3	0.4	7.6	0.5
Rotifera	71.2	19.8	37.5	2.6	21.8	27.9	21.1	1.3	4.6	0.1
Other Animals	11.9	0.7	31.3	1.1	34.5	1.7	17.5	0.5	62.1	4.2
Diatoms	49.2	-	56.3	-	41.2	-	73.7	-	?	-
Desmids	74.4	-	50.0	-	41.2	-	73.7	-	?	-

that the same food items were of approximately equal importance in the first three stages suggests that the species composition of the drift was approximately the same as that of the benthos with respect to micro-organisms. There appeared to be no major changes in diet associated with the shift in mouth position. Although the biomass of the food was not considered for small fish in this study, it is obvious that, until the fish were about 40 mm, chironomids and ostracods contribute the greatest part of the biomass. On occasion, however, the stomach was distended by a single baetid nymph or simuliid larva. While rotifers were generally eaten in small numbers, six suckers (21.5 to 22.5 mm long) captured on June 26, 1969, had consumed these organisms to the almost total exclusion of other forms. These six fish had eaten a total of 1175 food organisms of which 1124 were rotifers.

Stewart (1926) states that the "Fingerling Period" differs from the "Top-feeding Period" in that large amounts of sand are usually found in the alimentary tracts of fish during the "Fingerling Period", while little or no sand is found during the "Top-feeding Period." Stewart found sand to make up 27% and 21% of the volume of the stomach contents during the "Critical Period" and "Fingerling Period" respectively. By contrast, small suckers in the Bigoray River had consumed very little sand; the sand that was present contributed negligibly to the total volume.

The trend away from microscopic food organisms and toward larger forms begins in Stage IV and is accentuated in Stage V. For example, ostracods, copepods, cladocerans and rotifers, which accounted for 65.8% by numbers of the food of Stage III fish, made up just 34.9% of the diet in Stage IV and only 5.0% in Stage V fish. At the same time,

the corresponding values for Baetis and Simuliidae combined increased from 6.0% in Stage III to 28.1% in Stage IV to 68.9% in Stage V. This increase is considerably more pronounced for Simuliidae than for Baetis. Although both are typically riffle insects, Baetis is free-swimming and, therefore, not restricted to the riffle habitat; Simuliidae larvae, however, are almost completely restricted to fast water. Also, the simuliids are more likely to be encountered by the suckers because of their exposed position. Chironomid larvae continued to be important in the food of larger fish but relatively less so because of the increased availability of other forms. That the diet of Stage V fish is much more varied than in previous stages is indicated by the percent occurrence and percent numbers figures for the group "Other Animals" in Table XVII. Values for "Other Animals" greatly exceed the corresponding values of the other four stages.

Seasonal changes in food habits of fish-of-the-year

Table XVIII presents frequency of occurrence data for the major food items of young-of-the-year white suckers captured on seven collecting dates between June 12 and August 1, 1969. The corresponding percent numbers data are shown in Table XIX. The results are also illustrated graphically in Figure 20.

All fish-of-the-year were less than 40 mm long. As mentioned previously, the food habits of white suckers changed very little with the size of the fish up to a length of about 40 mm. The differences in the relative importance of the various food items shown in Tables XVIII and XIX and Figure 20 are thought to be related to fluctuations in the population densities of the food species.

The frequency of occurrence of chironomid larvae in the stomach

Table XVIII. Percent frequency of occurrence of major food items found in the stomachs of 187 young-of-the-year white suckers on seven collecting dates. (Number of fish in parentheses).

	June 12 (15)	June 20 (20)	June 26 (30)	July 3 (34)	July 17 (30)	July 24 (24)	Aug. 1 (34)
Chironomidae (Larvae)	100.0	100.0	90.0	100.0	100.0	100.0	94.1
Simuliidae (Larvae)	13.3	30.0	33.3	35.3	80.0	62.5	20.6
Ostracoda	46.7	60.0	86.7	97.1	83.3	62.5	52.9
Copepoda (Adults)	26.7	35.0	63.3	76.5	76.7	66.7	73.5
Copepoda (Nauplii)	13.3	20.0	33.3	52.9	26.7	16.7	26.5
Cladocera	13.3	30.0	26.7	41.2	90.0	66.7	58.8
Rotifera	53.3	55.0	86.7	70.6	-	8.3	2.9
<u>Baetis tricaudatus</u>	26.7	25.0	23.3	38.2	70.0	45.8	73.5
Other Animals	-	15.0	26.7	33.3	46.7	33.3	26.5
Diatoms	-	55.0	76.7	85.3	13.3	45.8	14.7
Desmids	73.3	60.0	86.7	88.2	13.3	29.2	29.4
Mean Length of fish (mm)	12.8	14.0	14.9	16.7	21.1	22.9	27.6

Table XIX. Percentage of total number of organisms recovered from the stomachs of 187 young-of-the-year white suckers on seven collecting dates. (Number of fish in parentheses).

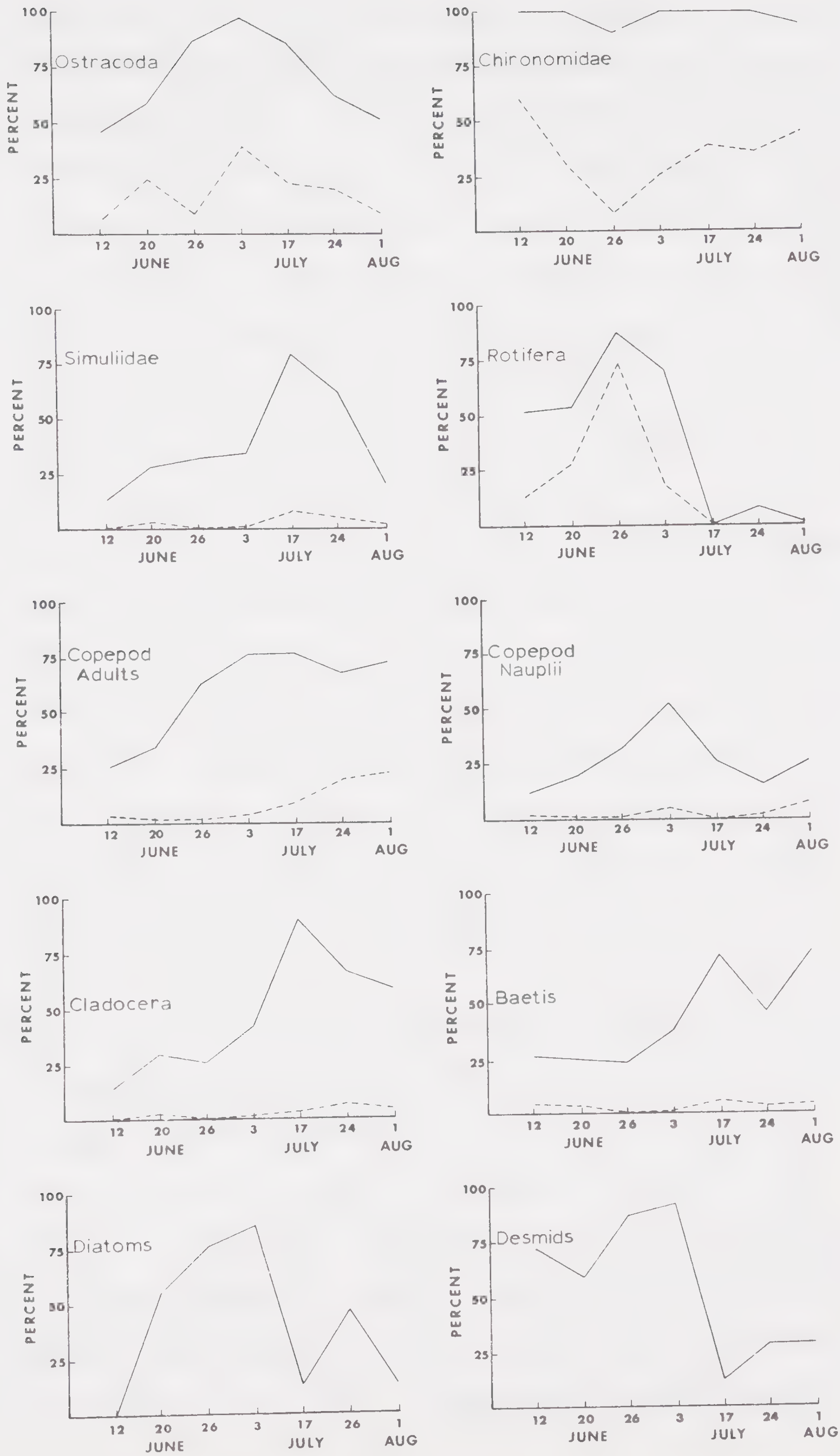
	June 12 (15)	June 20 (20)	June 26 (30)	July 3 (34)	July 17 (30)	July 24 (24)	Aug. 1 (34)
Chironomidae (Larvae)	65.2	32.2	10.8	26.8	40.6	36.7	46.3
Simuliidae (Larvae)	tr	3.1	tr	1.1	8.7	5.2	1.8
Ostracoda	6.8	25.0	9.3	39.1	23.0	20.2	9.8
Copepoda (Adults)	4.4	2.0	2.5	5.6	10.4	19.3	22.8
Copepoda (Nauplii)	2.4	1.1	1.4	7.0	tr	2.6	8.6
Cladocera	tr	2.8	tr	1.5	5.6	8.5	5.0
Rotifera	14.0	28.7	72.7	17.0	-	tr	tr
Baetis tricaudatus	5.3	4.6	tr	1.4	7.0	3.8	4.7
Other Animals	-	tr	tr	tr	3.8	3.1	tr
Total number of organisms in stomachs	207	457	1691	1699	1169	425	1059
Average number of organisms per stomach	13.8	22.9	56.3	50.0	39.0	17.7	31.1
Mean length of fish (mm)	12.8	14.0	14.9	16.7	21.1	22.9	27.6

tr - indicates less than 1.0%.

Figure 20. Percent frequency of occurrence and percent numbers of the major food organisms found in the stomachs of 187 young-of-the-year white suckers on seven collecting dates.

——————— Frequency of Occurrence

- - - - - Percent Numbers


Ostracoda
Chironomidae
Simuliidae
Rotifera
Copepod Adults
Copepod Nauplii
Cladocera
Baetis
Diatoms
Desmids
PERCENT
100
75
50
25
12
20
26
3
17
24
1
JUNE
JULY
AUG

contents fluctuated very little, remaining near 100% through June and July. Rotifers achieved a peak occurrence of 86.7% on June 26 and thereafter declined rapidly. After July 17, rotifers seldom appeared in the stomachs. The percentage of fish that consumed ostracods increased through June and reached a peak occurrence of 97.1% on July 3. The frequency of occurrence then declined gradually through July. The occurrence of adult copepods as food items also increased rapidly until July 3; thereafter the occurrence of adult copepods remained high, near 70%, through the end of the study. Copepod nauplii also occurred in an increasing percentage of the stomachs up to July 3, but after this date they declined in importance. Simuliid larvae, Cladocera and *Baetis* nymphs all reached occurrence peaks on July 17. The cladocerans exhibited the most drastic change. Cladocerans occurred in only 13.3% of the stomachs on June 12, but on July 17 were found in 90.0% of all stomachs examined. Their greatest increase occurred between June 26 and July 17. Diatoms and desmids were common in the stomach contents during June, but their occurrence dropped considerably after July 3. At no time during the summer did these algae contribute much to the diet in terms of biomass.

Chironomid larvae, ostracods, rotifers and copepods were the most abundant items in the stomach contents through June and July. Simuliid larvae, *Baetis* nymphs and Cladocera, on the other hand, contributed little in terms of numbers (Table XIX and Fig. 20). Figure 20 also shows a decrease in the percent numbers for ostracods and chironomids on June 26. These decreases, however, reflect more the appearance of an inordinately large number of rotifers in the June 26 sample than any pronounced tendency for the fish to consume fewer chironomids and

ostracods. This is illustrated in Figure 21, where the average number of each of these food items per stomach is plotted against each sampling date. The average number of rotifers per stomach increased from 2.0 on June 12 to 6.6 on June 20 and to 41.0 on June 26. The value then decreased to 8.5 on July 3. On July 17, no rotifers were found in the 30 stomachs examined. As mentioned previously, much of the high value for rotifers on June 26 is attributable to six fish that had consumed 1124 of these organisms. If these six fish are excluded from the counts, the average number of rotifers per stomach for the remaining 24 fish drops considerably.

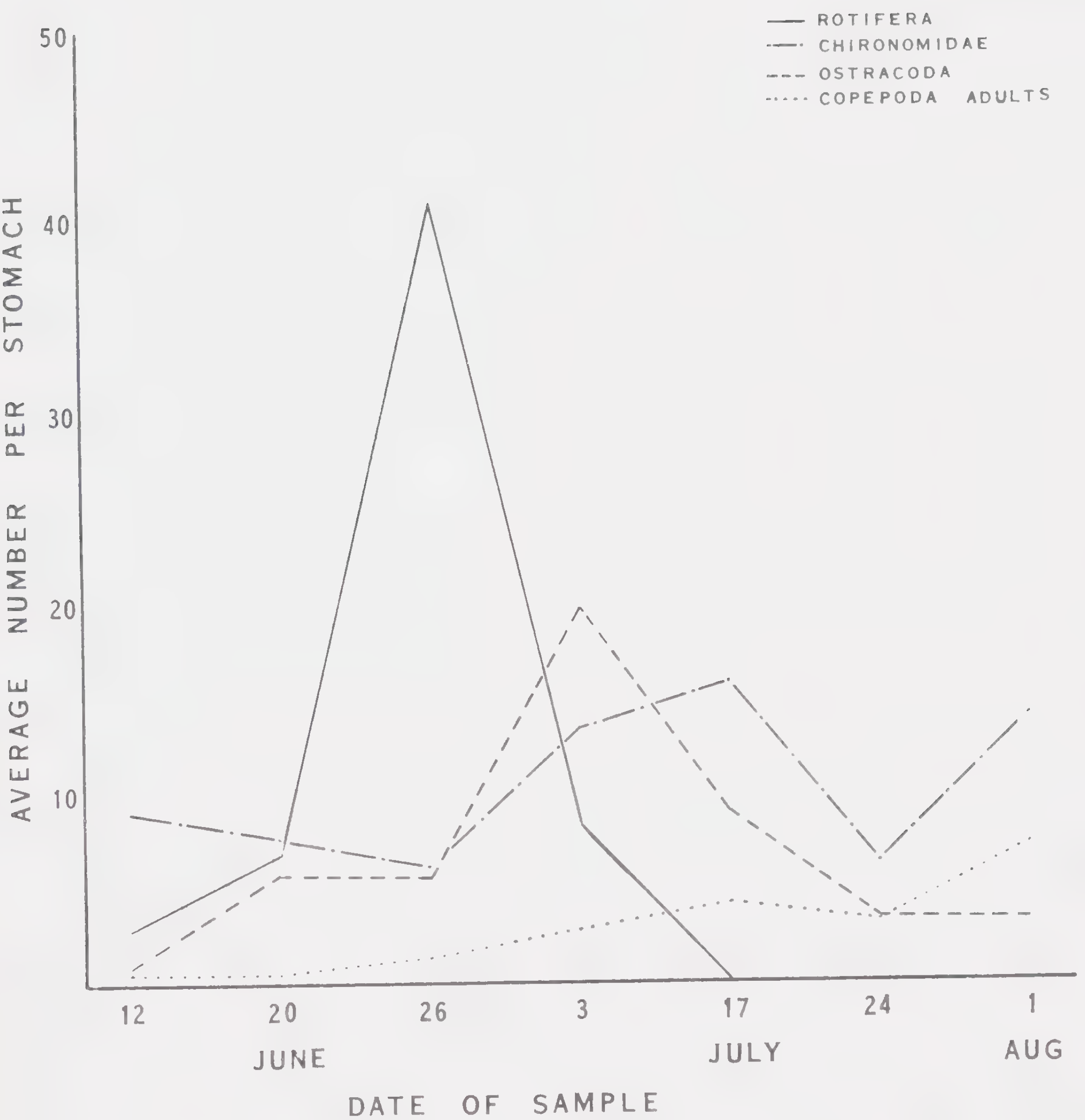
The average number of chironomid larvae in the stomachs decreased slightly throughout June, increased in early and mid July and decreased again in late July. Only 6.5 chironomids per stomach were found on July 24. This is indicative of the general decrease in food consumption by fish captured on this date (Table XIX).

The average number of ostracods eaten increased from 1.0 per fish on June 12 to 5.7 on June 20. There was a slight decrease on June 26 before the number increased to 19.4 on July 3. The average was 3.5 on July 24 and 3.1 on 1 August. Adult copepods made up only a small percentage of the total number of food items during June but became increasingly more numerous throughout July.

Seasonal changes in food habits of resident suckers

Adequate samples of resident fish could not be obtained for an extended period of time. However, fairly good samples were collected in October, 1968 and June, 1969. These fish will serve to point out the differences that may occur in food habits during different seasons of the year. These were 68 fish ranging from 32 to 196 mm in fork

Figure 21. Average number of food organisms found in the stomachs of young-of-the-year white suckers on seven collecting dates.


ROTIFERA
CHIRONOMIDAE
OSTRACODA
COPEPODA ADULTS
AVERAGE NUMBER PER STOMACH
50
40
30
20
10
12
20
26
3
17
24
1
JUNE
JULY
AUG
DATE OF SAMPLE

length, but only three were shorter than 40 mm and only three were longer than 83 millimeters.

Frequency of occurrence and percent numbers data for each collection date are shown in Tables XX and XXI respectively. These data indicate that the diet of resident white suckers was composed mainly of animal material during June of 1969. Chironomids, simuliids, Baetis and ostracods formed the bulk of the food at this time. There was an average of 61.4 food organisms in the stomachs of resident fish captured during June. Diatoms and desmids, while occurring in 53.0 to 79.0% of the stomachs during this period, generally appeared in small numbers and were relatively unimportant in terms of biomass.

In contrast to the June samples, the fish captured in October, 1968, contained an average of only 6.3 animal food organisms (Table XXI). This does not imply that the fish had ceased feeding. Instead, their digestive tracts were distended with diatoms. Of the 23 October fish examined, 10 fish contained nothing but diatoms and desmids. Desmids, however, occurred only in small numbers.

During October, 1968, the riffle insect fauna consisted of large numbers of hydropsychids and the stonefly Nemoura cinctipes. The mayflies Leptophlebia cupida and Callibaetis coloradensis were the dominant pool invertebrates at this time. These insects, however, were not utilized to any extent by resident white suckers during October. The explanation for this may lie in the growth characteristics of these insects. The new generations of all these insects appear during August and the nymphs and larvae grow rapidly during late summer and early autumn (Clifford, 1969). It seems likely, considering the small mouths of the young suckers, that by October the insects mentioned had grown

Table XX. Percent frequency of occurrence of major food items found in the stomachs of 68 resident white suckers on five collecting dates. (Number of fish in parentheses).

	- 1968 -			- 1969 -	
	Oct. 1 (8)	Oct. 26 (15)	June 12 (19)	June 20 (17)	June 26 (9)
Chironomidae(Larvae)	50.0	46.7	100.0	88.2	100.0
Simuliidae(Larvae)	-	-	68.4	70.6	66.7
Ostracoda	37.5	-	73.7	76.5	77.8
Copepoda(Adults)	25.0	33.3	68.4	52.9	55.6
Copepoda(Nauplii)	-	6.7	10.5	17.6	55.6
Cladocera	25.0	6.7	21.1	5.9	22.2
Rotifera	50.0	26.7	10.5	11.8	33.3
Baetis tricaudatus	12.5	-	89.5	76.5	55.6
Other Animals	12.5	-	21.1	23.2	44.4
Diatoms	100.0	100.0	57.9	53.0	77.8
Desmids	75.0	80.0	79.0	58.8	55.6
Mean length of fish(mm)	86.4	59.4	67.3	60.5	61.0

Table XXI. Percentage of total number of organisms recovered from the stomachs of 68 resident white suckers on five collecting dates. (Number of fish in parentheses).

	- 1968 -		- 1969 -		
	Oct. 1 (8)	Oct. 26 (15)	June 12 (19)	June 20 (17)	June 26 (9)
Chironomidae(Larvae)	31.2	31.9	29.6	42.1	39.2
Simuliidae(Larvae)	-	-	5.4	14.0	20.3
Ostracoda	13.0	-	21.4	20.9	27.0
Copepoda(Adults)	13.0	26.1	7.0	7.5	6.1
Copepoda(Nauplii)	-	18.8	tr	1.5	1.9
Cladocera	5.2	2.9	tr	tr	tr
Rotifera	26.0	20.3	tr	tr	tr
<u>Baetis</u> <u>tricaudatus</u>	5.2	-	34.8	12.6	3.7
Other Animals	6.5	-	tr	tr	tr
Total number of organisms in stomachs	77	69	1279	815	671
Average number of organisms per stomach	9.6	4.6	67.3	48.0	74.6
Mean length of fish (mm)	86.4	59.4	67.3	60.5	61.0

tr - indicates less than 1.0%.

too large for the fish to ingest them. Despite their numerical abundance, therefore, these insects were simply not available as food.

Another factor possibly contributing to the reduced utilization of animal food in autumn, 1968, may have been the dense growths of filamentous algae (*Microspora sp.*) which choked the riffle region of the stream and could provide excellent cover and protection for the invertebrate fauna. *Microspora* itself was not used as food to any extent.

Two young suckers were captured through the ice on November 24, 1968. One of these fish had eaten 36 chironomid larvae, 6 copepods, 1 small hydropsychid larva and 1 rotifer. The remainder of the stomach's volume was packed with diatoms. The stomach of the other fish contained only 1 chironomid, 1 copepod and a few diatoms.

It would appear, then, that the white sucker is highly adaptable in its food habits, being able to survive on plant material in the absence of available animal food.

The Macroinvertebrate Fauna of the Bigoray River

The Bigoray River supports a diverse bottom fauna, much of which is accounted for by five orders of insects, Ephemeroptera, Trichoptera, Plecoptera, Coleoptera and Diptera (Table XXII). The most common riffle insects are Chironomidae, Simuliidae, hydropsychids, *Baetis tricaudatus*, *Dicranota montana* and *Nemoura cinctipes*. The pool habitat is characterized by the presence of *Leptophlebia cupida*, *Callibaetis coloradensis*, Limnephilidae and Corixidae. Three summer mayfly species, *Siphlonurus alternatus*, *Cloeon sp.* and *Paraleptophlebia debilis*, are all pool species.

Percentage numbers and percentage wet weight data for the major riffle animals on each sampling date are shown in Tables XXIII and XXIV

Table XXII. Species list of aquatic invertebrates from the Bigoray River, showing the total number of each taxon collected during the study period.

Ephemeroptera	
Baetis tricaudatus Dodds	5084
Leptophlebia cupida (Say)	888
Callibaetis coloradensis Banks	476
Paraleptophlebia debilis (Walker)	129
Caenis simulans McD.	216
Siphlonurus alternatus (Say)	74
Cloeon sp.	53
Siphloplecton basale	22
Stenonema sp.	12
Ephemera simulans Walker	7
Hexagenia limbata (Serville)	4
Heptagenia sp.	3
Ephemerella sp.	1
Trichoptera	
Hydropsyche slossonae Banks	-
H. recurvata	-
Total Hydropsyche	1111
Cheumatopsyche analis Banks	1789
Arctopsyche sp.	2
Limnephilus infernalis Banks	-
Limnephilus spp.	-
Glyphotaelius hostilis Hagen	-
Total Limnephilidae	125
Oecetis sp.	99
Agraylea multipunctata	36
Unidentified Hydroptilidae	148
Brachycentrus americanus Banks	12
Ptilostomis ocelliffra (Walker)	5
Phryganea sp.	2
Glossosoma sp.	3
Plecoptera	
Nemoura cinctipes Banks	653
Capnia sp.	71
Archynopteryx sp.	26
Taeniopteryx nivalis (Fitch)	3
Coleoptera	
Adults (Not keyed)	303
Larvae-Dytiscinae	45
-Elmidae	527
-Hydroporinae	45
-Haliplidae	14
Diptera	
Chironomidae	12,179
Simulium venustum Say	-
S. tuberosum	-
S. vittatum Zett.	-
S. aureum	-
S. latipes	-
Total Simuliidae	3286
Dicranota montana Alex.	421
Tipula spp.	28
Chrysops sp.	7
Limnophora aequifrons	4

Table XXII. Cont.

Corixidae	271	Hirudinea	
		Glossiphonia complanata (L)	9
Anisoptera			
Aeschna subartica Walker	11	Hydracarina	72
Amphipoda		Oligochaeta	537
Hyallela azteca (Saussure)	307		
Gammarus lacustris Sars	17		
Gastropoda			
Physa heterostropha (Say)	-		
Helisoma sp.	-		
Total Gastropoda	23		
Pelecypoda			
Sphaeriidae	560		
Megaloptera			
Sialis cornuta Ross	64		

Table XXIII. Percent Numbers of major riffle invertebrates on each sampling date.

	1968									1969								
	Nov. 8	Dec. 8	Feb. 1	Feb. 15	Mar. 30	Apr. 18	May 3	May 18	May 30	June 12	June 26	July 10	July 24	Aug. 13	Aug. 27	Sep. 14	Oct. 5	Oct. 31
<u>Baetis tricaudatus</u>	18.3	5.0	2.1	5.2	3.9	0.8	7.8	8.9	56.4	41.7	11.4	0.8	49.8	17.6	49.6	51.8	25.4	17.6
<u>Hydropsyche spp.</u>	5.0	2.8	5.3	4.7	15.4	23.0	11.2	7.4	3.0	2.0	0.7	0.5	1.1	5.3	4.0	2.9	1.8	0.8
<u>Cheumatopsyche analis</u>	10.4	4.7	12.1	9.3	13.2	30.9	26.2	3.0	1.7	0.5	1.0	0.8	2.1	-	6.6	14.8	3.7	2.0
<u>Dicranota montana</u>	1.5	0.4	2.7	1.2	2.1	2.6	0.7	-	-	0.1	0.5	4.1	1.7	16.8	6.2	6.6	2.5	2.2
Simuliidae	4.0	0.1	-	-	-	-	-	52.8	26.6	45.8	6.8	2.6	26.0	10.7	6.2	2.5	57.5	55.9
<u>Nemoura cinctipes</u>	4.0	2.6	5.9	3.4	3.2	-	-	-	-	0.1	4.3	3.3	0.5	-	-	2.1	1.4	0.8
Chironomidae	53.0	78.8	66.4	71.1	59.3	34.4	48.1	22.4	7.6	6.5	55.2	66.1	10.3	19.1	13.1	0.8	1.6	14.1
Others	3.8	5.6	5.5	5.1	2.9	8.3	6.0	5.5	4.7	3.3	20.1	21.8	8.5	30.5	14.3	18.5	6.1	6.6

Table XXIV. Percent wet weight of major riffle invertebrates on each sampling date.

	1968		1969															
	Nov. 8	Dec. 8	Feb. 1	Feb. 15	Mar. 30	Apr. 18	May 3	May 18	May 30	June 12	June 26	July 10	July 24	Aug. 13	Aug. 27	Sep. 14	Oct. 5	Oct. 31
<u>Baetis tricaudatus</u>	1.8	1.0	0.3	0.2	0.2	-	2.0	10.4	21.4	9.9	6.8	-	33.7	22.2	56.6	56.0	3.5	6.1
<u>Hydropsyche spp.</u>	48.9	41.2	38.1	43.0	60.1	57.0	54.6	57.3	39.8	33.3	18.1	31.4	2.9	44.4	24.5	12.1	38.6	15.2
<u>Cheumatopsyche analis</u>	22.2	21.6	25.3	23.7	18.5	32.2	30.6	9.4	11.2	2.3	5.1	-	2.4	-	1.9	12.1	7.0	9.1
<u>Dicranota montana</u>	4.9	2.9	8.2	6.0	6.9	3.3	0.5	-	-	0.8	0.6	20.0	14.2	11.1	5.7	3.3	5.3	6.1
Simuliidae	1.8	-	-	-	-	-	-	10.4	12.2	49.2	9.0	2.9	22.0	-	1.9	-	26.3	30.3
<u>Nemoura cinctipes</u>	12.9	11.2	16.3	10.5	5.5	-	-	-	-	-	0.6	-	-	-	-	1.1	3.5	3.0
Chironomidae	2.2	8.5	6.7	12.3	4.6	1.2	5.6	4.2	1.0	2.7	17.0	14.3	3.4	-	-	-	-	-
Others	5.3	13.6	5.1	4.3	4.2	6.3	6.7	8.3	14.4	1.8	42.8	31.4	21.4	22.2	9.4	15.4	15.8	30.2

respectively. These data also appear graphically in Figure 22. Numerically, the chironomids were the dominant riffle organisms, but in terms of biomass their contribution was less important. The population density of chironomidae was at a minimum during September, but increased rapidly during late autumn. On December 8, 1968, chironomids comprised 78.8% of the total riffle fauna by numbers, a value that is undoubtedly low since many small larvae were unavoidably missed in picking the samples. Chironomids remained the most abundant riffle animals throughout the winter. During the spring and summer the abundance of chironomids, because of emergence, generally decreased, although their percentage values fluctuated greatly because of influxes and emergences of other taxa, especially Baetis and Simuliidae.

The hydropsychids, Hydropsyche spp. and Cheumatopsyche analis, dominated the riffle fauna in terms of biomass during the fall and winter months, making up as much as 89% of the total wet weight, and they also contributed substantially to the total number of organisms during this period. Both Hydropsyche and Cheumatopsyche pupate in May and emerge in late May and early June, with scattered emergences throughout the summer. In 1969, the new generations began to appear around the end of July and early August.

Nemoura cinctipes is the only stonefly found in abundance in the Bigoray River. Nemoura is the first aquatic insect to emerge in the spring. On March 30, 1969, several adults were found clinging to the underside of the ice cover. Emergence was completed by mid-April and the new generation began to appear about mid-June.

During the spring and summer of 1969, the riffle fauna of the Bigoray River was dominated, both in terms of numbers and biomass, by

Figure 22. Percentage composition in numbers and wet weight biomass for the major riffle invertebrates of the Bigoray River. Width of spindle is proportional to the number or wet weight of animals on each sampling date.

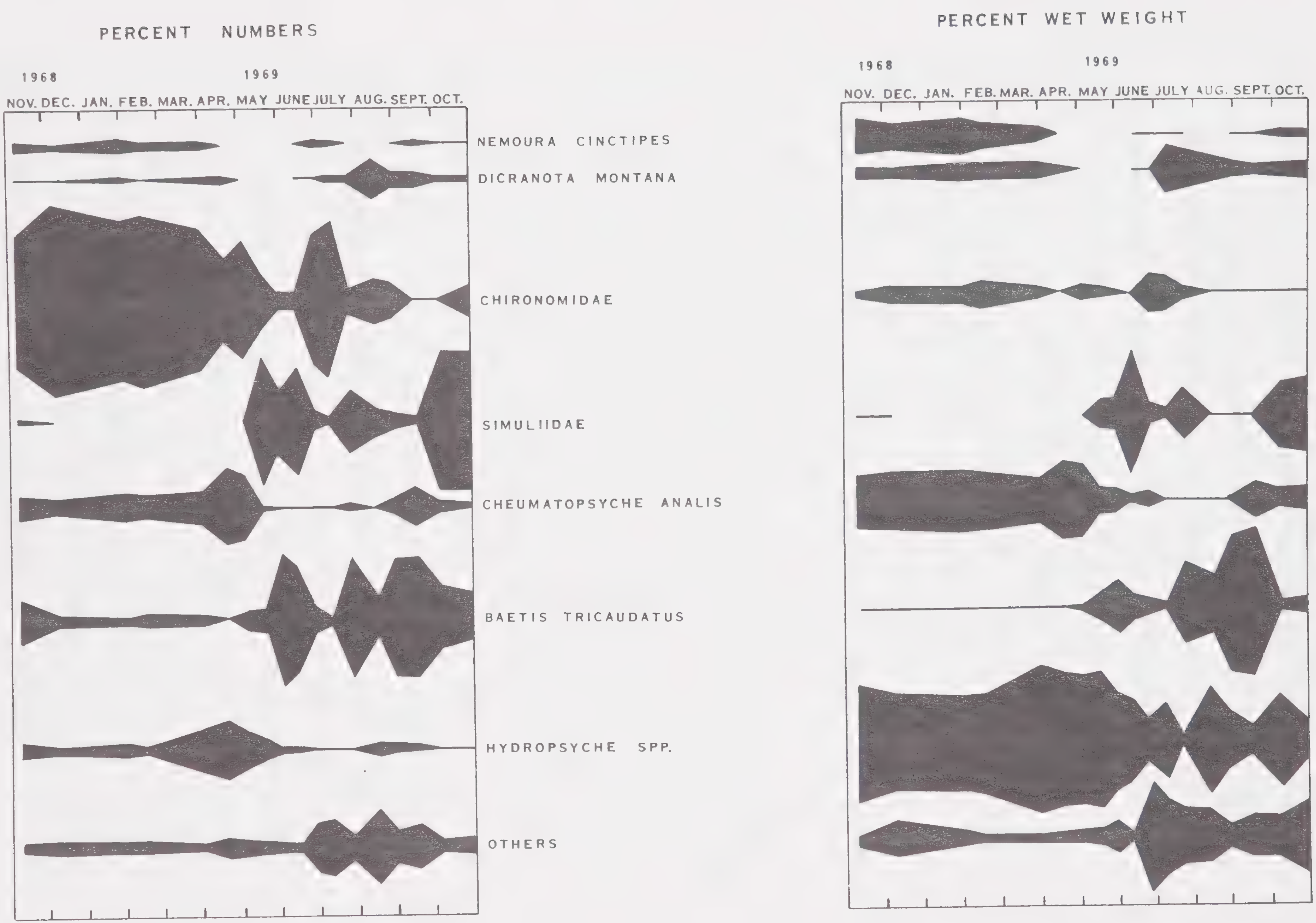

PERCENT NUMBERS
1968
1969
NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.
NEMOURA CINCTIPES
DICRANOTA MONTANA
CHIRONOMIDAE
SIMULIIDAE
CHEUMATOPSYCHE ANALIS
BAETIS TRICAUDATUS
HYDROPSYCHE SPP.
OTHERS
PERCENT WET WEIGHT
1968
1969
NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

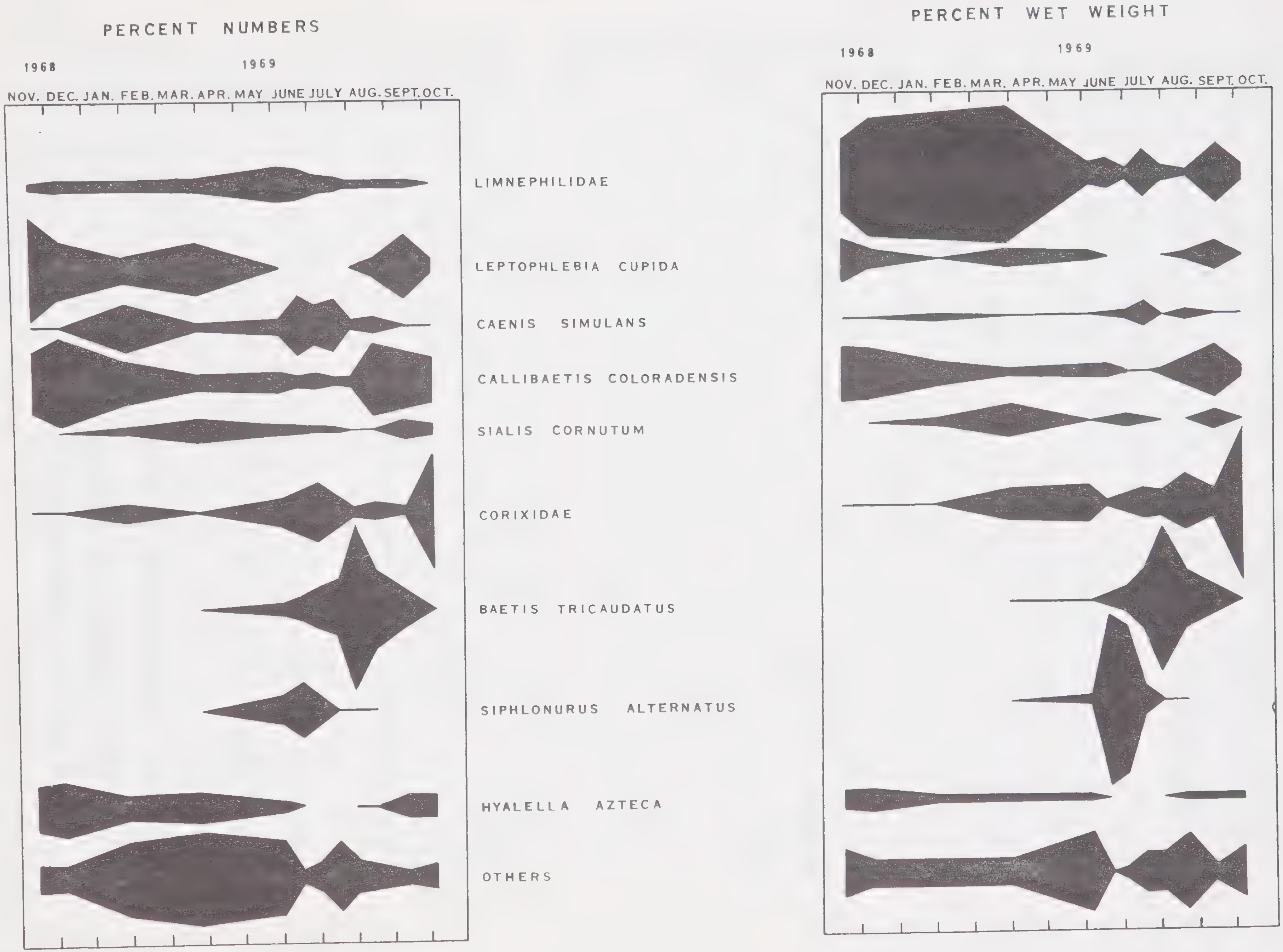
Table XXV. Percent numbers of major pool invertebrates on each sampling date.

	1968			1969								
	Nov. 15	Dec. 8	Feb. 1	Mar. 28	June 4	June 20	July 3	July 17	Aug. 1	Aug. 20	Sept. 14	Oct. 5
Leptophlebia cupida	41.4	25.3	9.9	21.3	1.3	-	-	-	-	6.3	27.3	6.3
Callibaetis coloradensis	25.3	38.6	17.1	6.7	7.8	3.6	6.0	2.2	3.9	30.4	25.1	18.9
Baetis tricaudatus	-	-	-	-	3.9	9.9	18.1	22.9	69.1	32.1	14.6	-
Limnephilidae	1.8	3.2	3.6	5.3	14.9	14.4	8.3	5.4	1.9	2.7	3.8	1.3
Corixidae	0.8	1.2	7.2	1.3	11.0	18.0	24.5	15.4	4.7	6.3	3.0	48.4
Siphlonurus alternatus	-	-	-	-	12.3	24.3	10.7	1.4	-	0.9	-	-
Sialis cornutum	-	-	1.8	9.3	3.9	1.8	3.7	2.5	0.3	-	8.6	5.0
Caenis simulans	0.6	-	19.8	2.7	5.8	23.4	17.1	21.2	4.7	7.1	1.5	1.3
Hyalella azteca	18.7	21.7	9.9	13.3	4.6	-	-	-	1.7	1.8	10.1	9.4
Others	11.4	10.0	30.7	40.1	34.5	4.6	11.6	29.0	13.7	12.4	6.0	9.4

Table XXVI. Percent wet weight of major pool invertebrates on each sampling date.

	1968				1969							
	Nov. 15	Dec. 8	Feb. 1	Mar. 28	June 4	June 20	July 3	July 17	Aug. 1	Aug. 20	Sept. 14	Oct. 5
<u>Leptophlebia</u> <u>cupida</u>	18.1	8.0	1.1	8.0	3.1	-	-	-	-	2.9	12.6	1.3
<u>Callibaetis</u> <u>coloradensis</u>	23.0	21.2	11.1	2.0	27.7	4.9	1.1	1.3	2.5	11.4	22.1	6.5
<u>Baetis</u> <u>tricaudatus</u>	-	-	-	-	1.5	2.4	9.7	26.0	62.5	22.9	10.5	-
Limnephilidae	31.7	50.4	55.6	59.3	9.2	12.2	5.4	20.8	5.0	2.9	26.3	7.8
Corixidae	0.8	0.9	13.3	0.7	15.4	2.4	8.6	13.0	11.3	22.9	11.6	61.7
<u>Siphlonurus</u> <u>alternatus</u>	-	-	-	-	3.1	73.2	64.5	11.7	-	-	-	-
<u>Sialis</u> <u>cornutum</u>	-	-	2.2	14.7	1.5	2.4	4.3	2.6	-	-	8.4	0.7
<u>Caenis</u> <u>simulans</u>	-	-	2.2	-	1.5	2.4	2.2	9.1	1.3	2.9	-	-
<u>Hyalella</u> <u>azteca</u>	7.4	8.0	3.3	4.0	3.1	-	-	-	1.3	2.9	2.1	2.0
Others	19.0	11.5	11.2	11.3	33.9	-	4.2	15.5	16.1	31.2	6.4	20.0

Figure 23. Percentage composition in numbers and wet weight biomass for the major pool invertebrates of the Bigoray River. Width of spindle is proportional to the number or wet weight of animals on each sampling date.


PERCENT NUMBERS
1968
1969
NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.
LIMNEPHILIDAE
LEPTOPHLEBIA CUPIDA
CAENIS SIMULANS
CALLIBAETIS COLORADENSIS
SIALIS CORNUTUM
CORIXIDAE
BAETIS TRICAUDATUS
SIPHLONURUS ALTERNATUS
HYALELLA AZTECA
OTHERS
PERCENT WET WEIGHT
1968
1969
NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT.

nymphs also grow rapidly during the late summer and fall and little or not at all during the winter. The main part of the 1969 emergence occurred in late May and June, but large Callibaetis nymphs were collected in small numbers throughout the summer.

Limnephilid larvae, while occurring in small numbers, made up as much as 60% of the pool biomass during the winter of 1968-69. In this respect, they were the dominant pool animals at this time. Limnephilid pupae were found during the first two weeks of May, 1969, and the new generation began to appear in the samples about mid-June.

Three summer, or temporary, species were found in the pool samples during the summer of 1969. Small Siphlonurus alternatus nymphs appeared around the first of June. They grew rapidly, and on June 20, represented 73.2% of the wet weight of the pool sample. Emergence was complete early in August. Paraleptophlebia debilis and Cloeon sp. were found from the first day of July until about mid-August, but never in large numbers.

Caenis simulans was common in the pool samples but contributed little to the biomass. Baetis, typically a riffle species, occurred in the pools in large numbers during July and August of 1969. Its occurrence in the pool habitat may have resulted from the floods of July 10 and August 6.

Clifford (1969), having considered the Bigoray River fauna in detail, described the aquatic insects as possessing the following characteristics:

(1) The aquatic insects have a restricted emergence period. About 80% of all emergence occurs during June and July. Nemoura, however, emerges in early April and Baetis continues to emerge well into October.

(2) There is a short period of seasonal succession for the fauna as a whole and, consequently, a long period when the fauna changes very little. Species present in October are also present in April. Some species grow throughout the winter; other species grow little or not at all, but no additional species appear as a result of hatching, and there is no emergence.

(3) Growth patterns of species are variable but the fauna as a whole grows more intensely in autumn. This results from the rapid growth of new generations of the dominant species -- L. cupida, Nemoura, Callibaetis and the hydropsychids.

(4) The appearance of three summer species, Cloeon, Siphlonurus and Paraleptophlebia causes considerable variation in community structure during June, July and August.

The life histories of the aquatic invertebrates and the growth characteristics of the species are of major importance in determining the extent to which they are utilized as food by stream fishes.

Relationship between the food of white suckers and the macroinvertebrate fauna of the Bigoray River.

The kind and amount of food eaten by a fish is a result of interactions between the fish and its environment, and in order to understand this, both units of the interaction should be studied (Hess and Schwartz, 1940). The availability of a food organism is a major factor in determining to what extent the organism will be eaten by fish. The term "availability", while implying numerical abundance, also involves the size of the food organism and its habits. Thus, an organism too large for the fish to ingest would be unavailable as food despite its numerical abundance. Also, a secretive or inactive species would be less available

than one that lived an active life in an exposed location.

Hess and Schwartz (1940) and Allen (1941) suggest that if the availability of all potential food organisms is equal, and if the fish feeds at random, then the prey organisms will occur in the food in proportion to their abundance in the fauna. On the other hand, if the composition of the food in the gut differs from that of the fauna, it is suggested that the availability of the food organisms in the fauna is not equal, or that the fish is tending to select certain organisms.

The data collected in my study are insufficient to permit the calculation of forage ratios or availability factors for the Bigoray River fauna. However, the fauna and the food can be compared in a general way and perhaps some conclusions reached as to the factors determining the extent of predation by white suckers on the invertebrate fauna of this stream.

No pool samples were taken from the Bigoray River during the spawning period. Riffle samples were collected on May 3, May 18, and May 30. With two exceptions, every taxon found in bottom samples during this period was also found in the stomachs of spawning suckers. Oligochaetes were never eaten, probably as a result of their burrowing habits. Capnia nymphs were also absent from the food, but these stoneflies were quite rare in the fauna.

Differences were found in the food of fish captured at different times of the spawning run (Table XXVII). The stomach contents of upstream migrants were dominated numerically by chironomid larvae, which comprised 57.4% of the total number of food organisms. Large limnephilid larvae, while making up less than 1.0% of the food by numbers, contributed 27.0% of the total wet weight. The remainder of the food biomass

Table XXVII. Frequency of occurrence, percent number and percent wet weight of major food items of adult white suckers during the upstream and downstream portions of the 1969 spawning migration.

	Upstream Fish (21 Fish) (Apr. 28 to May 26)			Downstream Fish (31 Fish) (May 24 to June 4)		
	Frequency Occurrence	Percent Number	Percent Wet Weight	Frequency Occurrence	Percent Number	Percent Wet Weight
Simuliidae Larvae	76.2	26.0	5.3	93.6	70.3	61.2
Chironomidae Larvae	85.7	57.4	13.5	96.8	9.7	6.1
Baetis tricaudatus	23.8	+	+	64.5	17.9	7.2
Limnephilidae	23.8	+	26.9	3.2	+	+
Leptophlebia cupida	43.8	2.4	10.0	22.6	+	3.0
Adult Beetles	23.8	1.7	6.4	16.1	+	5.1
Larval Beetles	28.6	+	1.2	19.4	+	+
Oecetis sp.	52.4	1.7	3.3	25.8	+	3.9
Hydropsyche spp.	9.5	+	3.7	19.4	+	7.7
Cheumatopsyche analis	19.1	+	1.3	16.1	+	+
Sialis cornuta	28.6	+	7.6	3.2	+	+
Corixidae	14.3	+	3.4	3.2	+	+
Gammarus lacustris	19.1	+	3.6	-	-	-
Dicranota montana	14.3	1.1	1.9	3.2	+	+
Hyalella azteca	14.3	+	+	-	-	-
Tipula sp.	14.3	+	2.3	12.9	+	+
Chrysops sp.	14.3	+	2.8	3.2	+	+
Siphloplecton basale	9.5	+	3.9	-	-	-
Caenis simulans	9.5	+	+	-	-	-
Callibaetis coloradensis	4.8	2.0	2.1	-	-	-
Others	28.6	2.5	+	21.2	2.0	4.0

+ Indicates less than 1.0%

of upstream fish was made up mainly of typically pool inhabiting species, (L. cupida: 10.0%; Sialis: 6.2%; Siphloplecton: 3.9%; Corixidae: 3.4%; Gammarus: 3.6%; adult Coleoptera: 6.4%; Chrysops: 2.8%; Tipula: 2.3% and Callibaetis: 2.1%). Chironomidae are found in large numbers in both the pool and riffle habitats. The only typically riffle animals eaten in quantity by upstream migrants were larval simuliids which made up 26.0% of the total food by numbers and 5.3% by wet weight. Most of these simuliids were eaten by fish captured near the end of the upstream migration.

Fish caught during the downstream portion of the spawning run had fed mainly on riffle type animals. Simuliid larvae occurred in 93.6% of the stomachs of downstream fish, accounting for 70.3% and 61.2% of the total food by numbers and wet weight respectively. The percent numbers and percent wet weight figures for Baetis nymphs were 17.9 and 7.2 respectively. Chironomid larvae were eaten in relatively smaller amounts by downstream fish than by upstream fish but still made up 9.7% of the food by numbers and 6.1% in terms of wet weight biomass.

Therefore the overall trend, from the beginning to the end of the spawning period, shows a change from feeding on pool species to feeding on typically riffle inhabiting animals. This trend is more evident when the fish of the upstream and downstream portions of the spawning migration are separated by sex (Table XXVIII). As mentioned earlier, the four categories of Table XXVIII represent stages occurring at successively later times in the spawning period, although they do overlap to some extent. The most pronounced changes of definitive food items of the suckers are those occurring in the limnephilids, chironomids, simuliids and Baetis nymphs. The limnephilids, while never numerous, made up 59.1% of the food of ripe males in terms of biomass, but only 9.5% of the food

Table XXVIII. Breakdown of percent numbers and percent wet weight of major food items of adult white suckers on the basis of sex and time of capture during the 1969 spawning migration. Number of fish in parenthesis.

	Ripe Males (5) Apr. 28 to May 20		Ripe Females (16) May 12 to May 26		Spent Females (14) May 16 to June 4		Spent Males (17) May 24 to June 4	
	Percent Number	Percent Wet Weight	Percent Number	Percent Wet Weight	Percent Number	Percent Wet Weight	Percent Number	Percent Wet Weight
Chironomidae	66.7	7.9	55.0	16.3	16.5	9.4	3.6	2.7
Simuliidae	3.5	0.1	28.7	8.2	49.5	15.5	81.1	83.3
<u>Baetis</u>	2.5	0.2	0.3	0.1	26.1	13.6	13.3	4.0
<u>Hydropsyche spp.</u>	-	-	0.3	5.6	0.6	20.2	0.1	0.8
<u>Cheumatopsyche</u>	0.5	0.8	0.3	1.6	0.3	2.1	tr	0.1
Limnephilidae	3.0	59.1	0.3	9.5	0.1	2.6	-	-
<u>L. cupida</u>	3.0	5.1	2.3	12.6	0.6	7.6	0.1	0.6
<u>Oecetis</u>	6.5	5.2	0.8	2.3	0.3	1.7	0.3	5.1
<u>Dicranota</u>	5.5	4.8	0.3	0.4	-	-	tr	0.3
Adult Beetles	0.5	1.1	1.9	9.3	0.3	12.1	0.1	1.5
<u>Sialis cornuta</u>	3.0	2.6	0.5	10.3	0.1	0.5	-	-
Others	5.3	13.1	9.3	23.8	5.6	14.7	0.4	1.6

of ripe females and only 2.6% of the food of spent females. Limnephilids were never eaten by spent males. A similar decrease occurred in the percent numbers figures for chironomid larvae. These larvae made up 66.7% of the total number of food organisms eaten by ripe males but only 3.6% of the food eaten by spent males. Simuliid larvae, which comprised a very small part of the food of ripe males, increased in importance as a food item throughout the spawning run and for spent males made up 81.0% of the total food by numbers and 83.3% by wet weight. Relatively, these figures are considerably higher than those of simuliids in the bottom samples (Table XXII and XXIII).

Three factors may explain the changes in diet observed for fish captured at different times during the spawning period. The study area was one of the few riffle regions on the Bigoray River. Downstream from this point the river is typically deeper and slower and consists almost entirely of pools. The upstream portion of the migration, therefore, took place mainly through pools and one would expect the food of upstream migrants to consist largely of pool dwelling organisms. In contrast, the time on the spawning grounds was spent in close proximity to riffle habitat and one might expect that riffle organisms would become more important in the diets of the fish at this time.

A second factor which might be expected to influence the composition of the food is the life histories of the food organisms themselves. Limnephilid larvae were pupating in early May and were, therefore, becoming less abundant in the fauna as the spawning migration progressed. L. cupida and Callibaetis both began to emerge in late May and their numbers were decreasing in the fauna at this time. The availability of hydropsychids also decreased during May as a result of pupation and

emergence.

Baetis nymphs and simuliid larvae both increased in abundance during May (Table XXIII). Collectively, these two groups made up 0.8% of the fauna in terms of numbers on April 18, 7.8% on May 3, 61.7% on May 13, 83.0% on May 30, and 87.5% on June 12. The corresponding wet weight figures for the same dates were 0, 2.0%, 20.8%, 33.6%, and 59.1% respectively. Simuliids were most abundant on May 18 (52.8%) and made up 49.2% of the fauna by wet weight on June 12. *Baetis* made up 56.4% of the fauna by numbers on May 30, at which time they accounted for 21.4% of the total wet weight biomass.

A third factor is that of selection. On May 30, *Baetis* nymphs were approximately twice as numerous in the fauna as the simuliids and the baetids made up about twice as much wet weight as simuliids. Yet the representation of these two groups in the food indicates that simuliids were eaten in far greater numbers than were the Baetids. It would appear that the simuliids were selected by the suckers in preference to the baetids, and it seems likely that this selection was the result of differences in the life styles of these two prey species.

SUMMARY

1. A study was made of the spawning migration, age and growth and food habits of the white sucker, Catostomus commersoni (Lacépède) in the Bigoray River, a small, brown-water stream of west central Alberta. Field work was carried out between October 1, 1968 and December 1, 1969.

2. In 1969, the spawning migration extended from May 10 to June 4. Suckers first entered the study area on the day the daily maximum water temperature first exceeded 10C. The upstream migration was most intense between 2100 and 2400 hours. Sixty percent of the spent fish were caught moving downstream between midnight and 0500 hours.

3. All white suckers involved in the spawning migration were mature. Males had an average fork length of 369 mm and ranged from 262 to 425 mm. Females averaged 384 mm with a range of 290 to 472 mm.

4. The overall sex ratio during the spawning migration did not deviate significantly from unity (42 males : 45 females), although variations did occur at certain times during the migration.

5. Spawners were found to be from 6 to 13 years in age with 8 and 9 year fish comprising 61% of the total number.

6. Male suckers were fully ripe on arrival at the spawning grounds. Females were not fully ripe on arrival, i.e., the ova could not be expressed without force.

7. The estimated number of eggs for 14 female suckers ranged from 15,983 to 60,242 with an average of 34,502 per female. The average length-relative fecundity was 915 ova per cm of fork length. The

average weight-relative fecundity was 46 ova per gram of body weight. Egg diameters ranged from 1.37 to 1.76 mm, tending to increase with the length of the fish.

8. Spawning occurred at all times of the day and night. Most of the spawning observed occurred in a moderate current at the base of a large pool over gravel that ranged in size from 0.5 to 50.0 mm in diameter.

9. Male and female suckers did not mingle on the spawning grounds until the female was ready to deposit her eggs, but the females remained out of sight in deep water. It was concluded that a major factor in determining a suitable spawning site was deep water adjacent to the site, to which the fish might retreat when alarmed.

10. Pearl organs were found only in male suckers. A fish captured on April 28 had begun to develop tubercles, but these were not as hard or sharp as those seen on fish later in the breeding season. By May 27, spent males had begun to shed their pearl organs.

11. Spawning first occurred between May 10 and May 13, 1969 and the first eggs hatched about May 28. The fry at hatching averaged 9.98 mm in total length. Eggs collected from the stream bed and hatched in a quart sealer indicated greater than 70% hatching success.

12. Newly hatched sucker fry began their downstream migration on the night of June 4. The fry at this time averaged 12.1 mm in length and only a remnant of the yolk sac remained.

13. The downstream migration of fry occurred mainly at night. The number caught per hour increased from sunset until midnight and then decreased until dawn. Few fry were caught during the daytime.

14. The scale ages were determined by counting the annuli. For fish up

to 9 years of age, the annuli were easily interpreted, but for suckers older than 9 years, the scale method is considered of questionable validity. Where doubt existed as to the validity of the scale age, otoliths were used to determine the age.

15. A correlation coefficient of 0.990 was found between the dorso-ventral scale diameter and fork length.

16. The data indicated a curvilinear relationship between dorso-ventral scale diameter and fork length. This relationship was described by the equation

$$L = 1.65859S^{0.76083}$$

where L is fork length and S is the dorso-ventral scale diameter.

17. Mean fork lengths at each annulus as calculated from the body-scale equation were as follows: I:52.7 mm; II:96.8 mm; III:139.7 mm; IV:184.0 mm; V:233.1 mm; VI:291.3 mm; VII:338.2 mm; VIII:367.3 mm; IX:391.0 mm; X:403.2 mm; XI:406.4 mm; XII:413.3 mm.

18. Calculated lengths closely approximated actual lengths for fish of age IV through age X. For fish of age I, II, and III, the actual lengths were less than the calculated lengths.

19. On the basis of calculated growth histories, white suckers increased in length at a uniform rate through the first 7 years of life. After age 7 the rate of growth decreased.

20. The mathematical relationship between fork length and body weight was determined to be

$$\log_e W = -11.77915 + 3.10052 \log_e L.$$

21. During their first growing season, white suckers in the Bigoray

River achieved a mean fork length of 42.2 mm and a mean body weight of 0.89 gram.

22. Young white suckers began to feed externally at a length of 11.5 - 12.0 mm. Until a length of 40 mm, the basic food of young suckers was chironomid larvae and ostracods. The secondary food items were cladocerans, copepods and their nauplii, rotifers, larval simuliids, *Baetis* nymphs, diatoms and desmids. Incidental food included various immature insects and a variety of algal forms. Sand was rarely found in the intestine.

23. There appeared to be no change in food habits as a result of the shift in mouth position in the young suckers, suggesting that the food occurred in the drift and in the benthos in approximately equal proportions.

24. At a length of about 40 mm, young suckers began to feed less on microscopic forms and to utilize more immature insects. This change is thought to be related to the ability of the young fish to maintain themselves in a strong current.

25. Adult suckers captured during the spawning migration had fed almost exclusively on immature insects. The basic foods of adult fish were limnephilid larvae, simuliid larvae, *Baetis* nymphs, and chironomid larvae. Secondary foods included *Leptophlebia* nymphs, larval hydropsychids and *Oecetis* sp., adult beetles and *Sialis cornuta*. An assortment of immature insects, molluscs, amphipods, and microcrustaceans were classed as incidental food.

26. The diet of adult suckers changed in composition during the month long spawning period in association with differences in habitat and the relative abundance of the various prey species. Simuliid larvae

appeared to be eaten preferentially and this was attributed to the exposed position that these larvae occupy on the substrate.

27. The relative importance of the various food items of first year fish varied through June and July, 1969. Chironomid larvae had the highest frequency of occurrence for all sampling dates. Their greatest contribution in terms of percent numbers occurred on June 12. Peak occurrences for the other major food items occurred on the following dates: Rotifers (June 26), Ostracods and copepods (July 3), Simuliidae and Cladocera (July 17), <u>Baetis</u> (July 17 and August 1), Diatoms and desmids (July 3).

28. Resident suckers fed mainly on animal food during June, 1969. On the other hand, residents captured in October, 1968 contained few animals and were feeding almost exclusively on diatoms. It is suggested that, although insects were available at this time, they were unavailable as food because the nymphs and larvae had become too large for the young suckers to ingest. Thus it appears that white suckers are capable of subsisting on plant material during periods when animal material is unavailable.

Closing Statement

It is felt that brown-water streams like the Bigoray River deserve more attention than biologists until now have devoted to them. While perhaps unimportant directly in a recreational sense, such streams undoubtedly play a most significant role in the ecology of northern Canada. Especially significant, perhaps, is their role as a hatchery for such forage fishes as the white sucker on which a large portion of our sports fishery depends.

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APPENDIX A. Physical and Chemical Features of the Bigoray River, October 8, 1968 - November 29, 1969.

Date	Calcium Hardness (ppm)	Total Hardness (ppm)	Total Alkalinity (ppm)	Iron (ppm)	Ortho Phosphate (ppm)	ph	Conductivity (umhos)	Turbidity (JTU's)	Apparent Colour (ppm)	Dissolved Oxygen (ppm)	Percent Saturation
Oct. 8/68	95	130	150	1.28	0.13	7.3	-	20	110	10.3	84
Nov. 8/68	120	160	185	1.35	0.24	7.2	380	25	120	10.2	80
Dec. 9/68	165	230	275	1.80	0.21	7.4	500	28	120	6.1	49
Jan. 18/69	180	255	325	0.88	0.22	7.3	575	25	80	7.0	55
Feb. 15/69	180	260	330	0.60	0.10	7.2	695	12	85	5.4	43
Mar. 16/69	175	260	320	0.53	0.12	7.3	650	15	40	7.7	61
Apr. 9/69	55	70	100	1.20	0.25	7.5	-	37	255	11.0	87
Apr. 17/69	30	40	40	0.68	0.30	7.0	125	60	265	11.2	88
May 9/69	40	55	60	0.48	0.25	7.2	-	40	190	9.8	94
May 23/69	50	70	75	0.60	0.21	7.6	-	38	170	-	-
June 4/69	60	90	110	0.65	0.19	7.4	260	35	-	-	-
June 19/69	100	130	160	0.55	0.18	7.9	280	30	130	-	-
June 26/69	100	140	175	0.56	0.20	7.7	310	25	120	8.4	91
July 17/69	55	95	110	1.25	0.20	7.7	190	48	240	8.4	90
Aug. 6/69	30	50	50	2.10	0.35	7.0	-	80	370	-	-
Aug. 20/69	70	100	110	0.98	0.40	7.3	-	56	230	7.3	78
Sept. 20/69	65	105	100	0.65	0.12	7.7	220	42	200	8.6	80
Oct. 26/69	60	80	95	0.81	0.08	8.1	200	26	156	11.4	89
Nov. 29/69	100	135	170	1.65	0.15	7.5	350	23	135	8.5	65